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EDITORIAL ANNOUNCEMENT

Professor Sten Friberg has announced his desire to retire as Editor of *Acta Orthopaedica Scandinavica*. The Scandinavian Orthopaedic Association has reluctantly accepted his resignation and wishes to express its appreciation of Dr Friberg's contribution to the *Acta* over the past generation. The high standards of the journal and its growth in circulation are greatly due to his dedication and ability.

The Editorial Committee of the Scandinavian Orthopaedic Association has taken this opportunity to re-organize the administration of the journal. An Editorial Board, consisting of the Editor and representatives from Denmark, Finland, Norway and Sweden, has been elected. A group of specialists has been invited to collaborate with the Editor to evaluate and select among the papers offered for publication. This service, which was introduced in 1970, will provide qualified review by experts from all sectors of orthopaedic science. We are confident that this re-organization will be of benefit to both contributors and readers.

Knud Jansen



ARNE BERTELSEN

11 October 1910 — 12 February 1971

IN MEMORIAM

Professor Arne Bertelsen one of the distinguished editors of Acta Orthopaedica Scandinavica is dead

In 1941 Arne Bertelsen joined the medical corps of the Finnish army later in the war he became assistant surgeon at the University Hospital in Copenhagen

The first three years after World War II Arne Bertelsen travelled to Sweden England Canada and the U S A to study plastic surgery and orthopaedic surgery His impressions during this tour were published as travelling letters in the Danish medical paper *Ugeskrift for Læger* and gave rise to a violent discussion among orthopaedic surgeons

Arne Bertelsen soon hereafter became senior registrar of Department I Orthopaedic Hospital in Copenhagen and in 1952 he was appointed head of the department

In 1953 Dr Bertelsen defended his thesis "Beiträge zur Frage der normalen Genese der Blutzellen He was then offered the chair in

anatomy at the University of Aarhus. However, he preferred clinical work and devoted himself to a career in surgery in Copenhagen.

Dr Bertelsen was from 1957 until his death professor of orthopaedic surgery at the University of Copenhagen.

Arne Bertelsen early recognized the risk that classic orthopaedics might become isolated as a subspeciality of the care and treatment of the physically handicapped, and he worked for an integration of orthopaedics and surgery. During his professorship it became generally accepted that orthopaedics should be orthopaedic surgery and that the speciality should include treatment of acute trauma of the extremities in connexion with the original field.

By his initiative a department for surgery of the hand was established in the Orthopaedic Hospital in 1957. An orthopaedic surgical department was established at the University Hospital in Copenhagen and from 1968 Professor Arne Bertelsen was head of this department. As a leader he had the gift of understanding his colleagues and for conferring responsibility on them. He was always ready to lend support by his warm confidence.

His research work was extensive and especially his study of pseudarthrosis of the long bones and the influence of bone marrow on regeneration of bone won international acknowledgement.

His humour and interest in history were elegantly demonstrated in a short funny paper "Fingers compensation and King Canute" written in collaboration with Norman Capener (*J. Bone Jt Surg.* (May 1960)).

Several young orthopaedic surgeons wrote their theses under the guidance of Prof. Bertelsen, who always followed the work closely and never let it collect dust on his desk.

During 1954–56 Dr Bertelsen was chairman of the Danish Orthopaedic Association; in 1962 he became an honorary member of the British Orthopaedic Association.

In 1960–62 Prof. Bertelsen was a member of the Danish Parliament.

Niels Stephensen

Department of Orthopaedic Surgery Malmo General Hospital
University of Lund Malmo Sweden

POST TRAUMATIC SYNDROME AND LIMB BLOOD FLOW

A preliminary Investigation

HELGE SEMB

Received x 1970

Fractures in the region of the wrist sometimes cause long functional disability of the joint Reduced painful wrist motion is the most frequent symptom However in a few cases classical so-called post traumatic dystrophy develops with oedema cyanosis tenderness painfull limited motion and spotty osteoporosis It has long been claimed that reflexly reduced capillary blood flow and stasis is the main cause of this syndrome (Dubois 1933 Bolliger 1954 Lenggenhager 1956 Thorban 1964) It has been suggested that the initial phase of osteoporosis is an effect of mineral dissolution which is favoured by tissue acidosis Though venous occlusion plethysmography has shown that the blood flow is increased in limbs with post traumatic dystrophy (Miller et al 1942) this acidosis has been assigned to sluggishness of the blood flow (Bolliger 1954 Lenggenhager 1956)

The present preliminary investigation was undertaken to obtain more objective data about the haemodynamics in post traumatic dystrophy

MATERIAL, METHODS AND RESULTS

The blood flow was measured in the forearms of three patients with typical post traumatic dystrophy after fractures in the carpal region The blood flow measurements were performed by venous occlusion plethysmography according to Dahn (1965) A water temperature of 34 was used Room temperature varied between 20–24 The patients were resting supine for 15 minutes before measurement The resting

Supported by grants from Riksforeningen mot Polio and from Alfred Österlunds Stiftelse

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Niels Stephensen

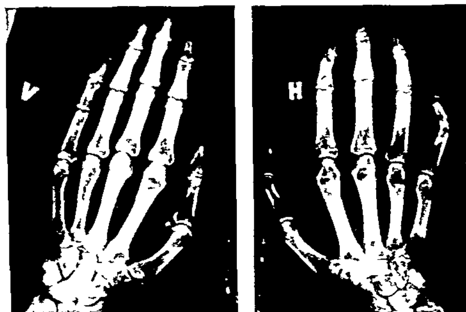


Figure 2 X ray of the hand skeleton of patient 2 Note the osteopenia of the right injured hand

the right hand (Figure 2) The patient was then admitted to hospital (13 January to 4 February 1969) for treatment with procain infusions elevation of the extremity and intense physical therapy Blood flow measurements on 30 January 1969 showed a fourfold increase of the resting flow through the right forearm The maximum flow was equal in both forearms (Figure 1) The symptoms gradually disappeared but the patient did not return to work until 14 November 1969 Eighteen months after injury the radiocarpal and finger joint were still stiff and painful and the wrist and fingers were weak. The skin temperature was normal and no oedema was demonstrable Blood flow measurements on 1 April 1970 17 months after injury showed a somewhat lower resting flow in the injured extremity There was no significant difference between the maximum blood flow through the right and left forearms (Figure 1)

Case 3 On 3 December 1968 a 46-year-old labourer fell and sustained an intraarticular Colle s fracture on the left side The fracture was reduced by manipulation under local anaesthesia and was immobilized in a plaster splint for five weeks Oedema osteoporosis and very limited painful motion were noted physical therapy was started but

without any demonstrable effect. The patient was therefore admitted to hospital (6 February to 22 February 1969) where he was treated with procain infusions, elevation of the extremity and physical therapy. *Some improvement was noted.* *On 6 February 1969 the resting* blood flow in the left forearm was increased threefold. Also the maximum blood flow was elevated in that arm (Figure 1). Continued ambulatory therapy resulted in slow recovery and the patient returned to work on 14 July 1969. At follow up 17 months after injury there was some limitation of strength and motion of the wrist. There was no pain or oedema and the skin temperature was normal. Blood flow measurements on 2 April 1970, 16 months after injury, showed normal resting blood flow in both forearms and a slight increase of the maximum *blood flow in the injured limb.*

DISCUSSION

Venous occlusion plethysmography measures the total inflow of blood into the limb segment inside the plethysmograph. The total blood flow through the forearm in the post traumatic syndrome is thus elevated after fractures in the region of the wrist. The results of the present investigation support the study by Miller et al (1942) but seem to be *incompatible with the earlier view that the post traumatic syndrome* is a result of capillary stasis.

It is emphasized, however, that an increased total blood flow through a limb segment does not necessarily mean an increased or even normal capillary or nutritional blood flow. On the contrary, in the post traumatic syndrome the cold cyanotic skin and the oedema reflect engorgement of the capillary blood circulation of the skin. In two patients (Case Nos 1 and 3), however, the maximum blood flow was also increased which implies an increased capillary flow through the muscles of the forearm in the injured extremity. *As the clinical condition improved* the total blood flow again became normal.

In this connection it is of interest that in disuse osteoporosis there is an increase of the total blood flow through the extremity (Imig et al 1953) as well as of that flow through bone (Shim 1966, Semb 1966). It has been suggested that the bone blood flow increase is a result of blood shunting through bone and bone marrow when the venous drainage is impaired by muscle inactivity (Semb 1966). The clinical picture of the post traumatic syndrome combined with increased total blood flow also suggests a shunt mechanism. Furthermore, disuse osteopo-

rosis is frequently combined with limited joint motion and oedema As previously pointed out by Geiser (1957) the similarity between the clinical symptoms and blood flow disturbances in disuse osteoporosis and post traumatic dystrophy suggests a close etiological relationship between the two conditions

SUMMARY

In a preliminary investigation the forearm blood flow was measured in patients with clinical and radiological signs of post traumatic dystrophy The resting blood flow through the forearm was significantly increased in the injured extremity with a successive decrease towards normal values as the clinical condition improved The similarity between post traumatic dystrophy and disuse osteoporosis is discussed

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Venous occlusion plethysmography measures the total inflow of blood into the limb segment inside the plethysmograph The total blood flow through the forearm in the post traumatic syndrome is thus elevated after fractures in the region of the wrist The results of the present investigation support the study by Miller et al (1942) but seem to be incompatible with the earlier view that the post traumatic syndrome is a result of capillary stasis

It is emphasized however that an increased total blood flow through a limb segment does not necessarily mean an increased or even normal capillary or nutritional blood flow On the contrary in the post traumatic syndrome the cold cyanotic skin and the oedema reflect engorgement of the capillary blood circulation of the skin In two patients (Case Nos 1 and 3) however the maximum blood flow was also increased which implies an increased capillary flow through the muscles of the forearm in the injured extremity As the clinical condition improved the total blood flow again became normal

In this connection it is of interest that in disuse osteoporosis there is an increase of the total blood flow through the extremity (Imig et al 1953) as well as of that flow through bone (Shim 1966 Semb 1966) It has been suggested that the bone blood flow increase is a result of blood shunting through bone and bone marrow when the venous drainage is impaired by muscle inactivity (Semb 1966) The clinical picture of the post traumatic syndrome combined with increased total blood flow also suggests a shunt mechanism Furthermore disuse osteopo

MATERIAL AND METHODS

Six adult mongrels were used They were anaesthetized with sodium pentobarbital (Nembutal®) intravenously in a dose of about 30 mg/kg bodyweight Twenty five milligrams of heparin was injected via the same route

The radioactive gas ^{133}Xe was used as clearance substance and the effect of vasoactive drugs on the marrow vessels was judged from changes in the slope of the elimination curves for ^{133}Xe deposited in the bone marrow Although ^{133}Xe has been found to be inappropriate as clearance substance for calculating the blood flow through the bone marrow (Semb 1970) it was found in a pilot study that the elimination rate of this radioactive tracer from the bone marrow was changed by vasoactive substances administered intraarterially or intravenously A small volume (0.3–0.5 cc) of a solution of ^{133}Xe (0.15 mCi) was slowly injected proximally in the bone marrow of each tibia via cannulas inserted through the cortex This was immediately followed by injection of a small volume of isotonic saline sufficient for rinsing the cannula via a three way stop-cock

In four animals in which ^{133}Xe had been previously deposited bilaterally in the tibial bone marrow various vasoactive drugs were injected intraarterially via a thin polyethylene catheter into one femoral artery and through a polyethylene catheter into a subcutaneous vein of one foreleg The drugs tested were adrenaline nor adrenaline histamine acetylcholine and bradykinin The doses used were so small as to have only a negligible effect on the arterial blood pressure when given i a They correspond to those used in earlier investigations on the effect of vasoactive drugs on the bone marrow circulation (McPherson et al 1961 Shaw 1963)

The effect of histamine injected into the bone marrow on the bone marrow circulation was studied in two dogs In this separate study ^{133}Xe was supplemented by ^{131}I a tracer which in a pilot study was cleared about four times more rapidly than the lipophilic Xenon [illegible] was included as a clearance substance because it should be more sensitive to transient changes in the bone marrow blood flow

The radioactivity was measured by two collimated scintillation detectors located over the regions where the tracer was deposited [illegible] counts were recorded on a ratemeter connected to a [illegible] recorder When a mixture of ^{133}Xe and ^{131}I was injected [illegible] region pulse height analysis was used and correction was [illegible] the ^{131}I impulses recorded by the ^{133}Xe-channel

The systemic arterial blood pressure was measured in one carotid artery. A polyethylene catheter filled with saline was inserted into the artery and was connected to a pressure transducer (Elema Schönander, Stockholm, Sweden). The pressure was recorded on a mingograph recorder. Calibration was performed against atmospheric air and saline corresponding to a pressure of 50 mm Hg.

RESULTS

Each of the drugs tested (adrenaline, noradrenaline, histamine, acetylcholine and bradykinin) produced an obvious and prompt effect of two to three minutes duration on the disappearance curves of ^{133}Xe.

Adrenaline. Intraarterial injection of adrenaline (0.05 μg/kg) reduced the elimination rate of ^{133}Xe in the ipsilateral leg. The effect on the arterial blood pressure was negligible (Figure 1). Adrenaline (0.5 μg/kg) i.v. resulted in impaired clearance in both legs. There was a transient decrease of the arterial blood pressure followed by a small increase for about one minute.

Noradrenaline. Noradrenaline i.a. (0.3 μg/kg) like adrenaline resulted in reduction of the disappearance rate of Xenon in the same leg. No change in the arterial blood pressure was observed (Figure 1). Noradrenaline i.v. (2.0 μg/kg) impaired ^{133}Xe clearance in both legs. The arterial pressure rose 20 to 40 mm Hg for about two minutes (Figure 2).

Histamine. The disappearance rate of ^{133}Xe decreased after injection of histamine (1.0 μg/kg) into the femoral artery of the same leg

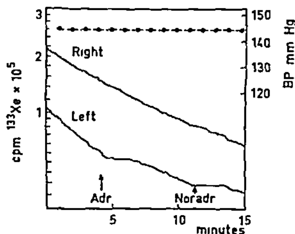


Figure 1. Effect of intraarterial adrenaline and noradrenaline on the disappearance rate of intramedullary deposited ^{133}Xe and on the systemic arterial blood pressure. Note the unaffected blood pressure and the insignificant effect on the disappearance rate of ^{133}Xe in the contralateral leg.

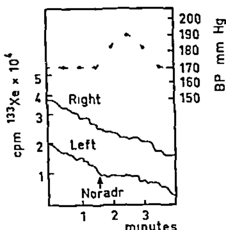


Figure 2 Effect of intravenous noradrenaline on the disappearance rate of ^{133}Xe administered in the bone marrow and on the systemic arterial blood pressure Note the pronounced effect on the blood pressure and the symmetric impairment of the disappearance rate of ^{133}Xe bilaterally

A negligible transient fall in pressure was seen (Figure 3) Histamine i v (2 0 μg/kg) however resulted in a more pronounced decrease of the arterial pressure and impaired ^{133}Xe clearance in both legs

Acetylcholine After intraarterial deposition of acetylcholine (0 5 μg/kg) the disappearance rate of Xenon was decreased in the ipsilateral leg There was a pressure fall of maximum 30 mm Hg for a few seconds (Figure 4) Acetylcholine i v (5 0 μg/kg) impaired the ^{133}Xe-clearance bilaterally and resulted in a pressure drop to about 50 mm Hg for half a minute

Bradykinin Bradykinin i a (0 3 μg/kg) yielded a small reduction

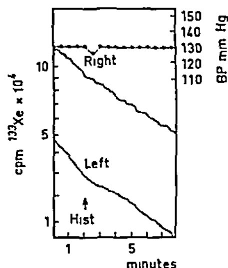


Figure 3 Effect of intraarterial histamine on the disappearance rate of intramedullarily deposited ^{133}Xe and on the systemic arterial blood pressure Note the insignificant effects on the blood pressure and on the disappearance rate of ^{133}Xe in the contralateral leg

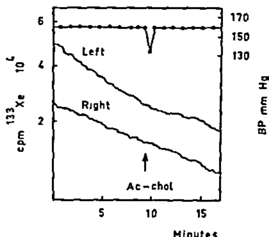


Figure 4 Effect on the ^{133}*Xe clearance from the bone marrow and the arterial blood pressure after intraarterial acetylcholine*

of the ^{133}Xe clearance in the same leg The arterial pressure was unaffected Bradykinin i v (2 0 µg/kg) resulted in a slight bilateral decrease of the disappearance rate The blood pressure dropped ten to 20 mm Hg for about one minute

Deposition of histamine in the bone marrow of the tibia in the same region as the tracer substances (^{133}Xe and ^{131}I$^-$) had previously been administered and resulted in two minutes enhanced clearance of both substances especially of ^{131}I (Figure 5)

The clearance of the test substance ceased completely in one leg after occlusion of the ipsilateral femoral vein

DISCUSSION

^{133}Xe was used as a clearance substance in this study first because a pilot study had shown that there was a prompt change of its disappearance rate after intraarterial administration of vasoactive substances and second because it is a tracer that is very easy to handle

The local clearance of ^{133}Xe from the bone marrow of the tibia was affected in an unexpected way by administration in the ipsilateral femoral artery of histamine acetylcholine and bradykinin vasoactive drugs known to dilate vessels in other regions

Administration of vasoactive substances could impair the regional capillary blood flow by a central effect on the arterial blood pressure or by a peripheral vasomotor effect It was found however that the systemic effect of the vaso-dilating drugs was negligible after intra arterial injection This was reflected by a very slight change of the



Figure 5 Effect of histamine injected into the bone marrow on the disappearance rate of 133Xe previously deposited in the same region

continuousl\ recorded blood pressure and b\ an unaffected disappearance rate of the tracer from the bone marrow of the contra lateral tibia Thus there was a local effect of the intraarteriall\ injected substances It seems strange however that normall\ vasodilators such as histamine and bradykinin could decrease the elimination rate of the tracer 133Xe On the other hand the apparentl\ paradoxical reaction of the bone marrow vessels might be explained b\ vasodilatation with lowered resistance and enhanced blood flow in surrounding muscles This might cause an increase of the blood flow through the muscles at the expense of that through the bone marrow of the limb Deposition of one vasodilator substance histamine directl\ into the bone marrow in the same dose as administered intraarteriall\ raised the capillar\ blood flow in the same region which implies a regional vasodilation This finding suggests that in spite of their peculiar anatom\ the bone marrow vessels can respond to vasomotor stimuli It seems probable however that the vasomotor response of the thin walled bone marrow arteries is weaker than that of the muscle arteries This supports the suggestion that the reduced bone marrow blood flow following deposition of vasodilator substances in the ipsi lateral femoral arter\ ma\ be an effect of redistribution of blood flow between bone marrow and surrounding muscles due to more active dilatation of the blood vessels of the muscles compared with that of the bone marrow vessels

As expected intravenous injection of acetylcholine and histamine resulted in a marked drop of the arterial blood pressure This drop was probabl\ the main cause of the impaired elimination of 133Xe from the bone marrow The possibilit\ of a central haemodynamic effect

after intravenous injection is supported by the finding of a parallell decrease of the ^{133}Xe clearance in both legs After intravenous administration of noradrenaline however the blood pressure increased whereas the bone marrow clearance of ^{133}Xe decreased implying a systemic as well as a regional vasoconstrictor effect of noradrenaline

The effect of intraarterially and intravenously administered vasoactive drugs on the bone marrow blood flow in cats has been studied by Shaw (1963) who used heated thermocouples for qualitative measurement of the regional blood flow He found that adrenaline noradrenaline and acetylcholine decreased the marrow blood flow observations which were confirmed in the present investigation He also found that acetylcholine increased muscle blood flow This supports the theory presented above i e vasodilators cause a redistribution of the blood flow in a limb However he found that histamine i v increased the bone marrow flow in contrast with the present findings and with those of Branemark (1961) who found that such treatment dilated capillaries and sinusoids but decreased the blood flow through the fibular bone marrow in rabbits

Occlusion of the femoral vein has been found to increase the blood flow through the femoral bone marrow in cats owing to a shunting of blood through the bone marrow cavity (Shaw 1963) However, in the present investigation the immediate effect of the same procedure was complete inhibition of the disappearance of ^{133}Xe in the tibial bone marrow obviously as an effect of increased venous pressure It must be emphasized however that venous stasis of the tibial bone marrow as an effect of venous occlusion in the thigh does not preclude the possibility of blood shunting proximally via the femoral bone marrow

SUMMARY

The effect of vasoactive drugs on the bone marrow blood vessels was studied in dogs Changes in the disappearance rate of ^{133}Xe deposited locally in the tibial bone marrow were recorded after intraarterial and intravenous injection of the drugs Adrenaline noradrenaline acetylcholine histamine and bradykinin decreased the disappearance rate However intramedullary deposition of one vasodilator substance histamine resulted in enhanced elimination of ^{133}Xe It is concluded that the bone marrow vessels have the ability to respond to stimuli of vasomotor drugs in spite of their structural peculiarity Intraarterial administration of vasodilator drugs probably causes a redistribution of the blood

flow through the limb viz an increase in flow through the muscles at the expense of that through the bone marrow

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Department of Orthopaedic Surgery
Malmo General Hospital University of Lund Malmo Sweden

ENZYME STUDIES OF FRACTURES WITH NORMAL AND DELAYED UNION

C GUDMUNDSON & H SEMB

Accepted 1 xii 1970

Fracture healing has been extensively studied by morphological methods (e g Enneking 1948 Pritchard & Ruzicka 1950) Cell proliferation in healing bones has been studied by autoradiographic technique (Tonna & Cronkite 1961) The mineral accretion and turnover (Bauer 1954) as well as collagen synthesis and turnover (Stacher & Firschein 1967) have also been studied in experimental fractures The glycosaminoglycans have been identified in fracture callus by Solheim (1965)

The mechanism underlying the development of delayed fracture healing or non union is however still obscure The uptake of phosphorus is increased irrespective of the rate of healing (Bohr 1955) Wendeberg (1961) found the uptake of strontium in healing tibial shaft fractures in man to be increased to roughly the same extent whether healing was normal or delayed A slight disturbance of the distribution of glycosaminoglycans has been demonstrated on one occasion in pseudarthrosis of the human femur (Solheim 1966)

Some publications are available on the role played by enzymes in bone repair Thus alkaline phosphatase (Pritchard & Ruzicka 1950) oxidative enzymes (Balogh & Hajek 1965) and esterases (Rackallio & Makinen 1968) have been demonstrated histochemically in fracture callus Lactic dehydrogenase activity and isoenzymes have been studied in regenerating rabbit bone (Bruce & Strachan 1967 Gudmundson & Semb 1970)

The purpose of this study was to elucidate the activity and subfractions (isoenzymes) of some enzymes in callus tissue from fractures with normal and delayed union Rat femur fractures were used because they frequently heal very slowly (Bohr 1955 Pritchard & Ruzicka 1950)

MATERIAL AND METHODS

Forty mature female Sprague Dawley rats eighteen months of age weighing 24? ± 18 (S D) grams at the beginning of the experiment, were used. Their left femur was manually broken in the middle of the diaphysis under ether anaesthesia No att mpt was made to immobilize the fractures Eight weeks later the right femur was broken with the same technique The animals were kept in three large cages and were fed a standard laboratory diet with water *ad libitum* Immediately after fracture the animals walked on three legs but within a few days on all four

The animals were killed fifteen weeks after the first fracture The fracture of the right femur was then seven weeks old Both femurs were dissected and X rayed Femurs with stable and unstable fractures were grouped separately according to fracture age The fracture area was cleaned of soft tissues and the callus was removed for enzyme analyses Specimens of callus tissue from healed and unhealed fracture respectively of each fracture age were randomly divided into four groups

Specimens from diaphyses of femurs obtained from adult female rats weighing about 250 grams were used as controls Furthermore six pooled samples of fracture callus from twenty one week old rat femur fractures were used for com parison of the isoenzyme pattern of esterases in later healing stages All these frac tures were stably healed

The specimens were kept on ice and their blood was removed by rinsing them in isotonic saline at + 4 The specimens were then deep frozen in liquid nitrogen and crushed to powder in an ice-cold steel mortar (Semb 1970)

Extraction was performed overnight at + 4 in distilled water in the propor tions ? 1 (v/w) The extracts were centrifuged at + 4 and 10 000 *g* for five minutes and the supernatants were used for the analyses after dilution with distilled water The total activity of lactic dehydrogenase (LDH) was measured spectrophoto metrically as described earlier (Semb 1970) After addition of sodium pyruvate in phosphate buffer 0 1 M pH 7 4 and NAD H dissolved in 0 001 N NaOH the decrease in light absorption was measured at 340 mμ This is a measure of the oxidation of NAD H which is a function of LDH activity The activity was expressed as units one unit being equivalent to an extinction decrease of 0 001 per minute per millilitre of th sample

The tartrate inhibited acid phosphatase (Acpase) activity was determined spectrophotometrically according to Jacobsson (1960) Samples of the tissue ex tracts were added to p nitrophenyl phosphate di sodium salt, 0 4 per cent, in citrate buffer pH 5 5 After incubation at 37 the amount of p nitrophenol liberated was measured photometrically at 405 mμ in a Beckman B spectrophotometer The total activity of alkaline phosphatase (Alkpase) was measured according to the same principle using p nitro phenyl phosphate as substrate with the exception that a buffer with pH 11 0—11 3 (2 amino 2 metyl 1 propanol + $MgSO_4$) was used

All values of enzyme activity were related to the wet weight of the specimens and also to the DNA concentration The DNA content was estimated using the diphenylamine reaction (Dische 1930)

LDH isoenzyme were separated by electrophoresis on agar gel and were identified by incubation at 37 in a substrate mixture containing lithium lactate NAD and nitroblue tetrazolium as coupler as described by Semb (1970) The density of the

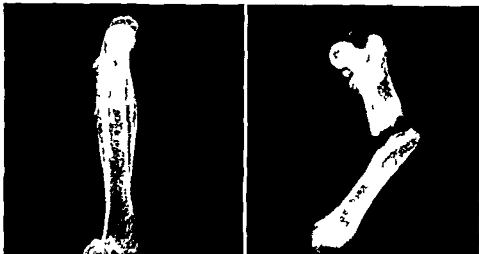


Figure 1 Fifteen weel old fractures of the rat femur with normal (left) and delayed (right) union

LDH isoenzymes was measured in a Vitatron photometer with a scanning device and an automatic recorder

Esterases and Alkpase and Acpase were examined by starch gel electrophoresis according to Smithies (1955) The starch gel was cast on glass plates which were placed on top of the plexiglass electrophoresis tank and were continuously cooled with tap water Esterases and Acpase were separated in Ashton buffer pH 8 6 and Alkpase in borate buffer pH 8 5

For identification esterases were incubated at 37 overnight in α naphtyl acetate phosphate buffer pH 7 0 and Fast Red TR salt as coupler Alkpase was incubated in α naphtylacid phosphate sodium salt Tris buffer pH 8 6 and Fast Blue RR salt After preincubation at 37 in acetate buffer pH 4 0 for 40 minutes Acpase was identified by incubation in α naphtyl acid phosphate sodium salt acetate buffer pH 5 2 and Fast Blue RR salt

RESULTS

The type of fracture healing was assessed by testing the stability of the femur diaphyses by hand Of the seven week old fractures 17 were not healed (43 per cent) and 12 fractures (30 per cent) were not healed after fifteen weeks The X ray films (Figure 1) invariably confirmed the type of healing recorded

During the studied period of 15 weeks the weight gain of the animals amounted to 39 ± 7 (S D) grams There was no difference in weight gain or carcass weight between rats with stably healed fractures and rats with one or two fractures with delayed union ($p > 0 2$)

Table 1 Enzyme activities (units ± S.D) in callus from fractures with normal and delayed union

	Stable fract 7 weeks	Unstable fract 7 weeks	Stable fract 15 weeks	Unstable fract 15 weeks	Normal bone
lkpase /g	424 ±40	160 ±11	250 ±47	152 ± 6	169 ±39
lkpase /mg DNA	235 ±23	77 ± 5	191 ±36	111 ± 4	252 ±56
cpase /g	83 ±19	149 ±20	88 ±15	104 ±11	45 ± 5
cpase /mg DNA	48 ±11	71 ±10	67 ±11	76 ± 8	64 ± 7
DH /g × 10^3	61 3±13 2	72 4± 3 9	71 8± 8 1	63 5±12 8	9 2± 2 4
DH /mg DNA × 10^3	35 2± 7 6	34 6± 1 9	54 7± 6 2	46 3± 9 3	10 3± 3 4

The total activity of LDH was increased in healed as well as in un healed fractures of both seven and fifteen weeks of age (Table 1) This increase was always highly significant ($p < 0\ 001$) whether relating the activity to wet weight or DNA concentration

Alkpase activity was in the same range in normal bone as in frac tures with normal union as compared to the DNA content However the Alkpase activity was significantly higher in stable fractures than in unstable ones after seven ($p < 0\ 001$) as well as after fifteen ($0\ 01 > p > 0\ 001$) weeks irrespective of whether the activity was correlated with wet weight or DNA content (Table 1 Figure 2)

Acpase activity was most increased in unhealed fractures after both periods (Table 1 Figure 2) The difference in Acpase activity was however only statistically significant after a healing period of seven weeks ($0\ 01 > p > 0\ 001$) and insignificant after fifteen weeks ($p > 5$ % [1]) When correlated with the DNA concentration there was neither any significant Acpase activity difference between control bone and healing bone with delayed union nor between control bone and fifteen week old stably healed bone

After electrophoreses of Alkpase and Acpase in starch gel only one fraction of each enzyme could be seen This fraction had the same electrophoretic mobility whether extracted from normal bone or from callus

Electrophoretic separation of esterases revealed some differences

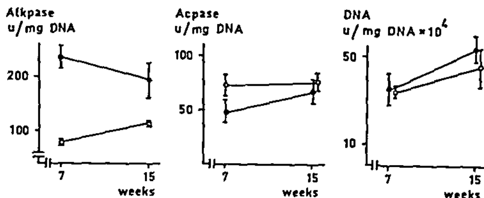


Figure 2 Total activity of alkaline and acid phosphatases and of lactic dehydrogenase (units/mg DNA ± S D) in seven and fifteen week old fractures with normal (●——●) and delayed (○——○) union

between normal bone and fracture callus Both tissues showed two main fractions a slow one and a fast one But the fast fraction was more active in callus tissue than in normal diaphyseal bone There was no difference between healed and unhealed fractures in this respect However in callus from twenty one week old fractures the slow fraction was more active than the fast one (Figure 3) Thus the esterase zymograms of twenty one week old fractures resembled those of normal diaphyseal bone

Five distinct zones of LDH were seen after electrophoretic separation on agar gel (Figure 4) In normal diaphyseal rat bone LDH 5 is predominant (42 per cent) In stable as well as in unstable fractures the activity of LDH 1 was significantly ($p < 5\%$) lower and that of LDH 5 significantly higher than the corresponding isoenzyme activities

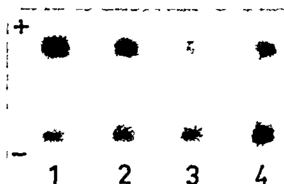
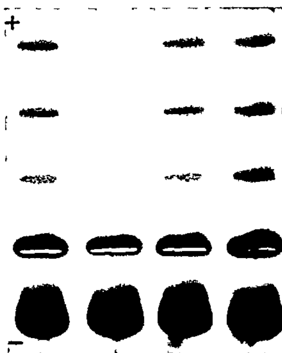


Figure 3 Isoenzymes of esterases in fifteen week old stable fractures (1-2) and in twenty one week old stable fractures (3-4)

Figure 4 Isoenzymes of lactic dehydrogenase in fifteen week old stable fractures



in normal bone Stable fractures of seven weeks of age displayed the most pronounced increase in LDH 5 activity and correspondingly the most pronounced decrease in LDH 1 activity These differences were significant ($p < 5$ %) as compared with the activity in the callus from the other fractures as well as with that in the normal bone Comparison between stable and unstable fifteen week old fractures did not reveal any significant difference in the LDH isoenzyme pattern (Figure 5)

DISCUSSION

Some factors are known to be able to delay or prevent union of fractures e g, regional impairment of blood flow insufficient immobilization and infection But sometimes delayed union cannot be ascribed to any of these known factors Previous investigations have demonstrated a normal uptake of phosphorus in rat femoral fractures with delayed union (Bohr 1955) and of strontium in pseudarthrosis of the tibia in man (Wendeberg 1961) However no investigations have been published of enzymes in fractures with delayed union or non union

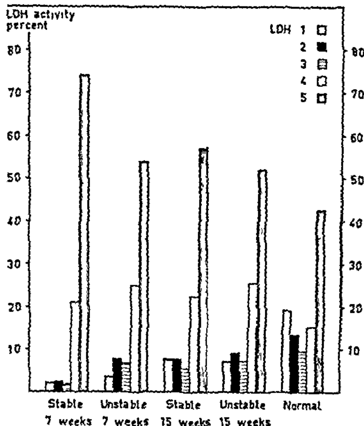


Figure 5 Percentage activity of lactic dehydrogenase isoen ymes in callus from seven and fifteen week old fractures with normal and delayed union and in normal rat femoral diaphyses

In this study fractures of the rat femur were chosen because such fractures often heal slowly or result in delayed union (Bohr 1955) The frequency of delayed union after seven and fifteen weeks was very high (about 35 per cent) However most fractures of the rat femur seem to heal spontaneously after some time Thus all fractures observed at twenty one weeks were healed It must be emphasized however that twenty one weeks is a long part of the rat s life span

The function of Alkpase is still obscure but it is in some way related to the mineralization process A normal mineral uptake has been found in fractures with delayed union (Bohr 1955) and in pseudarthroses of the tibia (Wendeberg 1961) However in our inves tigation Alkpase activity was significantly lower in fractures with delayed union as compared to normally healing fractures It has been

suggested that Alkpase limits the accumulation of calcification inhibitors e g inorganic pyrophosphate (Jibril 1967) Moreover serum Alkpase activity increases significantly long before the mineralization process of the fracture callus begins (Semb et al 1970) Thus the enzyme is probably of considerable importance in the premineralization phase of fracture healing and the decreased enzyme activity of our fractures with delayed union may be an important limiting factor for a normal fracture healing

No difference in electrophoretic mobility of Alkpase was found Only one fraction was seen in all preparations which is in accordance with some earlier investigations of isoenzymes of Alkpase in serum bone and other tissues (Hodson et al 1962 Hill & Sammons 1967)

It has been found that Acpase belongs to lysosome-like particles in bone cells (Vaes 1965) Increased activity of this enzyme has been demonstrated in bone with an increased resorption rate induced by parathyroid hormone (Vaes 1967) In the present investigation Acpase activity was higher in fractures with delayed union than in normally healing fractures particularly after seven weeks

During bone formation the highest activity of Acpase has been found in the osteoclasts (Buring & Semb 1970) which implies that this enzyme is of importance in the bone remodelling The increased Acpase activity in fractures with delayed union may result in a high remodelling rate which is in accordance with reported data on mineral uptake in fractures with delayed union or pseudarthroses (Bohr 1955 Wendeberg 1961)

A high activity of LDH has been demonstrated histochemically in osteoblasts as well as in osteoclasts in healing fractures (Balogh & Hajek 1965) In the present investigation the activity of LDH an oxidative enzyme was increased to about the same level independent of normal or delayed fracture healing These results support the theory about a high remodelling rate also in fractures with delayed union

The LDH isoenzymes are tetramers of two polypeptide subunits called H and M LDH 1 = HHHH LDH 2 = HHHM etc *In vitro* a predominance of H in tissues with aerobic metabolism has been found On the other hand there is a preponderance of M in tissues with anaerobic metabolism (Hellung Larsen 1968) In the present investigation the activity of LDH 5 was higher and that of LDH 1 was lower in stable seven week old fractures than in callus from the other fractures Moreover on comparison between all kinds of callus tissue and normal diaphyseal bone the relative activity of LDH 5 was higher and that

of LDH 1 lower in callus tissue (Figure 5) This implies a more anaerobic metabolism in callus than in normal bone and a predominance of that kind of metabolism in stable seven week old fractures Thus in healing rat femur fractures and especially in those with the fastest healing rate there might be an increased oxygen demand or relative ischaemia in spite of the profuse blood supply

SUMMARY

Enzyme studies were performed on seven and fifteen week old rat femoral fractures with normal or delayed union The frequency of delayed union was about thirty five per cent

Alkaline phosphatase activity was higher in stable fractures than in unstable ones particularly at seven weeks On the other hand acid phosphatase activity was somewhat higher in fractures with delayed union No change was seen in the isoenzyme patterns of alkaline or acid phosphatases

The total activity of lactic dehydrogenase (LDH) was higher in fractures than in normal bone irrespective of the stage or duration of healing of the fracture There was a preponderance of LDH 5 isoenzyme in normal bone as well as in callus but this isoenzyme was more active in callus than in bone

The enzyme studies suggest a more anaerobic metabolism in callus than in normal diaphyseal bone and may indicate a high remodelling rate also in fractures with delayed union

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Figure 1 Roentgenogram of the left hand showing th areas of markedly increased radiodensity in the proximal and middle phalanges of the left middle finger the second and third metacarpal bones the capitate and lunate bones and the distal end of the ulna

carpal bones the capitate and lunate bones and the distal end of the ulna (Figure 1) Cortex was markedly thickened and outline of the middle phalanx and the third metacarpal bone was distorted Other sclerosed bones were all endosteal or cortical

Laboratory studies, including complete blood count, urinalysis plasma alkaline phosphatase serum calcium and phosphorus and serum proteins were all within normal limits

Resection of the thickened cortices of the middle phalanx and the third meta carpal bone was performed on 11 January 1967 Grossly the periosteum was normal in appearance and the cortical bone appeared something like a stalactite

Microscopic examination of the protruding mass revealed fibrosis in the surround ing connective tissue and active membranous ossification along the margin of the bone The pattern of the Haversian systems in the underlying bone tissue was irregular in most areas (Figure 2) When examined under the polarizing microscope the bone tissue consisted mainly of fibrous bone and matrices around the vascular spaces were replaced by lamellar bone There were no islands of cartilage with evidence of endochondral ossification and no inflammatory vascular change

COMMENT

Pain stiffness swelling and deformity are the frequent symptoms and signs but only characteristic X rays establish the diagnosis There are continuous or interrupted streaks or blotches of sclerotic bone along a part or the whole of a tubular bone suggestive of the flow of wax down a lighted candle Diagnosis in a typical case is easy but



Figure 2 Photomicrograph showing fibrosis in the surrounding connective tissue membranous ossification and irregular pattern of Haversian systems (Hematoxylin and eosin × 130)

as Walker (1964) states difficult cases are occasionally encountered He reported two cases of mixed sclerosing bone dystrophies which showed characteristics of osteopoikilosis osteopathia striata and melorheostosis

According to Morris et al (1963) Ernsting (1966) and Campbell et al (1968) increased or decreased length deformities such as club foot and genu varum scleroderma lymphedema and hemangioma are often associated with this condition Involvement of the epiphyseal cartilage by osseous lesion is thought to be responsible for occurrence of these limb deformities Muller et al (1963) reported seven cases of melorheostosis accompanied by linear scleroderma and suggested that linear scleroderma may represent a primary mesenchymal defect that occasionally spreads into the skeletal tissues There is no satisfactory explanation for the remaining soft tissue abnormalities

Biopsy findings in our cases are consistent with these reports except islands of cartilage with the evidence of endochondral ossification The absence of cartilage formation and endochondral ossification may be due to the situation that the biopsy specimens were from the diaphyseal lesions (Campbell et al 1968) Furthermore we could not find in flammatory vascular change in our specimens which was suggested by Morris et al (1963)

MICRORADIOGRAPHIC INVESTIGATIONS

In 1946 Engstrom described a quantitative method for determining the amount of calcium salts in bone using microradiographic tech niques Since that time refinements in the technique and their theory (Engstrom 1949 1962 Lindstrom 1955 Hoh et al 1959) and exten sion of its field of application have provided valuable information about the distribution of various substances especially hydroxyapatite (Wallgren 1957 Holmstrand 1957 Nilsonne 1959 Ericsson 1965) in microscopic level

To register the quantitative microradiograms an X ray unit of high stability (Philips PW 1010) equipped with a copper target was run at 20 kV and 16 mA The resultant radiation was then filtered through a 0 02 mm nickel filter Under these conditions relatively good monochromatisation was obtained and it was estimated by Wallgren (1957) and Holmstrand (1957) that more than 80 per cent of the radiation which passed through the nickel lay in the wave length range 1 5 to 1 6 Å the major part being derived from CuKα radiation

A thin ground section of biopsy specimen with a step wedge of aluminium foils on Kodak Spectroscopic Plate 649 was exposed to this relatively monochromatic CuKα radiation After developing the plate the microdensitometry was performed Comparing the micro-photometric readings of the image of the specimen and the correspond ing steps in the wedge the amounts of hydroxyapatite per unit area can be calculated In order to know the amounts of hydroxyapatite per unit volume it is necessary to measure the thickness of the section In this study the section was cut with a microdissection knife so that all of the points to be measured came to lie at the free cut edge The thickness of cut edges was measured by micrometry in a profile micro-scope employing reflected light

Figure 3 shows two different part of the same microradiogram of

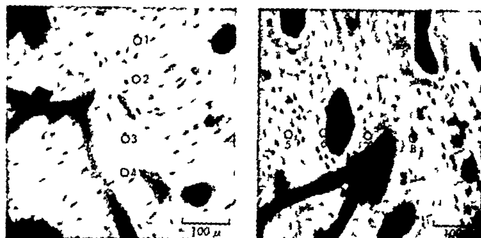


Figure 3 Two different areas of the same microradiogram The observed density of the specimen at the indicated points is as follows

Points	Density (gm hydroxyapatite per cm³)
1	1.05
2	1.09
3	1.07
4	1.12
5	0.93
6	1.02
7	0.94
8	0.94

the specimen The observed density of the specimen at the indicated points is tabulated These are the representative points among the forty points measured The density (grams of hydroxyapatite per cubic centimeter) of the many points of this specimen lay between 1.12 and 0.93 g cm⁻³ The density of pure hydroxyapatite is 3.15 g cm⁻³ (Rowland 1959) if calculated on the basis of the unit cell dimension given by Carlstrom (1955) Then the percentage by volume of hydroxyapatite of the measured points of our specimen lay between 36 and 30 per cent These values of the specimen are never higher than those of normal human bones

Gross changes in mineralization are usually diagnosed by visual inspection of the clinical radiogram but we must always keep in mind that the clinical radiogram is a superimposed image of innumerable structures within the bone and that visual inspection of black and white in a radiogram would deceive us so that we would have a tremendous difference in mineral content per unit volume The micro-

scopic density measured revealed that the mineral content per unit volume of the melorheosteotic bone is not higher than that in the normal bone

SUMMARY

An additional case of melorheostosis is reported The mineral content per unit volume of the melorheostotic bone of this case was within normal limits

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Hospital for Extrapulmonary Tuberculosis Juelsminde Denmark

ACTINOMYCOSIS OF THE SPINE

Report of two cases

J ERNST & F RATJEN

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The first description of *human* actinomycosis was given by Israël in 1878 and Israel & Wolff (1891) isolated anaerobic actinomyces in pure culture from patients and obtained takes on inoculation into animals

Pus obtained from patients with actinomycosis contains one or more of four actinomyces strains In about 50 per cent of all cases Actinomyces Israeli is present However most pus samples also contain other micro-organisms especially Bact actinomycetem comitans anearobic streptococci and Esch coli (Holm 1950 1951)

The portal of entry is the oral cavity the respiratory or gastro-intestinal tract (then frequently the appendix)

The infection spreads in the directions where the tissue resistance is least often along vessels and nerves to the prevertebral space of the neck the posterior mediastinum and to the retroperitoneal space

The skeletal system may become involved mainly by contiguity but apart from the jaw this is a relatively rare occurrence

Grassner (1929) found osseous involvement in 15 per cent of 486 patients with the following distribution spine 37 per cent mandible 25 per cent ribs 10 per cent maxilla 8 per cent

The first comprehensive description of actinomycosis of the spine was given by Bostrom in 1891 His description is accompanied by a picture which in an excellent way illustrates the patho-anatomy of the disease which forms the basis of the radiographic findings

Erving (1902) reported that the frequency with which actinomycosis involves vertebrae and ribs is 2 per cent So far 68 cases of spondylitis caused by actinomycosis have been published in the world literature

A search of the Scandinavian literature has revealed four Danish cases of which the first three had been subjected to autopsy (Ammentorp 1893 Eiken 1942 Glahn 1950 Zacho 1942)

The patho anatomical findings in actinomycosis of the spine have been described in detail by numerous authors (Parker 1923 Simpson & McIntosh 1927 Beitzke 1934 Meyer & Gale 1935 Cope 1951)

The spine is attacked by propagation of a paravertebral phlegmon Erosion of the surfaces of several vertebral bodies occurs once the peri osteum is *penetrated It is a feature characteristic of the individual* vertebrae that the pedicles transverse processes and other parts of the arches are involved The medial ends of the ribs may become eroded on account of propagation from the pleura or spine

Only in rare cases does the propagating osteomyelitis give rise to destruction of intervertebral discs (Parker 1923 Haselhorst 1928 Flynn & Gillies 1938 Dixon 1939 Lubert 1944 Brett 1951 Young 1960) or to the development of external pachymeningitis

Multiple ostia from abscesses may occur on the skin of the nape of the neck or back

Even though in the autopsy reports the vertebral bodies are de scribed as being soft on section collapse with gibbus formation and medullary compression is rare The explanation is probably that the osteoclastic destruction of the bony tissue is accompanied by a reactive formation of new bone imparting to the vertebrae a moth eaten spon gy or honeycomb-like appearance

Symptoms Actinomycosis of the spine as a complication of the cer vicofacial pulmonary mediastinal or abdominal variety is at first characterised by a remarkable stiffness of the involved vertebral seg ments later possibly followed by neurological manifestations In ad vanced cases sinus tracts will be present especially on the nape of the neck and the back

The diagnosis is based on the demonstration of the pathogenic acti nomyces and the accompanying bacterial flora already mentioned However since the pathogenic strains of actinomyces are highly sensi tive to penicillin and streptomycin pus from patients treated with these drugs will reveal growth only of he accompanying bacterial flora

Histological examination of a biopsy specimen may be helpful Radio graphy must also be regarded as a valuable aid in the diagnosis this applies in particular to tomography (Lubert 1944)

Radiographic Findings The number of publications of the radio graphic appearance of spinal actinomycosis is small as compared with those considering its pathological features (Parker 1923 Tabb & Tucker 1933 Lubert 1944 Young 1960)

The anterior and lateral surfaces of the vertebral bodies have an irre

gular saw toothed appearance caused by periosteal new bone formation

The central parts of the vertebrae are characterised by a honeycomb-like structure produced by destructions surrounded by newly formed sclerotic bone

Very often the pedicles processes and arch as well as the interarticular joints are also involved Compression of the vertebral bodies and destruction of the intervertebral discs rarely occur and there are no sequestra or calcifications in the accompanying paravertebral abscesses

In the radiographic differential diagnosis tuberculosis should particularly be considered Not infrequently spinal actinomycosis is for a long time misdiagnosed as tuberculosis

More remote diagnostic possibilities are metastases in the spine myelomatosis osteitis deformans (Paget) syphilitic spondylitis and other bone mycoses

Since a correct diagnosis is a prerequisite for adequate treatment and as it appears from the literature that the differential diagnostic possibities are numerous we find it of interest to report two cases of actinomycosis of the spine encountered in the Hospital for Extrapulmonary Tuberculosis Juelsminde

Case reports

Case 1 The patient was a girl aged 17 For four years she had suffered from dental caries of increasing severity During the last two years she had a number of healing but recurrent abscesses of varying localisation on the neck. At the same time increasing painless stiffnes of the neck developed A skin biopsy specimen from the margin of one of the abscesses revealed inflammatory infiltrations and actinomyces grains.

On admission to the Hospital for Extrapulmonary Tuberculosis Juelsminde in November 1968 the patient was almost cachectic weight 38 5 kg height 154 cm In the nape of the neck and on the upper part of the back there were scars of four healed abscesses and four fresh abscess perforations There were no enlarged axillary or cervical lymph nodes The neck was stiff held in a slightly stooping position E.S.R 115 mm/h Hgb 90 & W B C. 10 950 temperature 37 ° C. No cough or expectoration

Radiography of the *spine* including tomography revealed a periosteal reaction of the spine and at the external lamina of the occiput a honeycomb-like structure of the vertebral bodies in the cervical and the thoracic region as well as in the transverse processes and the upper ribs ill defined demarcations of several intervertebral spaces obliteration of the joint space of the interarticular joint C_2/C_3 and a slight compression of the body of Th_8 Anteroposterior and lateral views demonstrated a paravertebral shadow

Chest radiography revealed a large infiltration in the upper right lung field with



Figure 1 Case 1 girl aged 17 years
Cervical spine tomography lateral view

a *Before chemotherapy Jagged periosteal new bone formation particularly at the anterior margins of the vertebral bodies of* C_4–C_6

b *After treatment Organised ossification of the periostal new bone formation The trabecular structure of the bodies is normal*

c *Left apophyseal joints of the cervical spine Before treatment Articular margins irregular*

d *Same after treatment Ankylosis between* C_3/C_4 *and* C_6/C_7

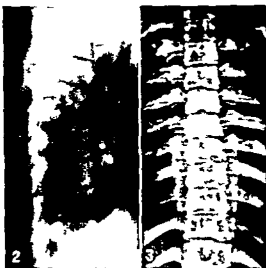


Figure 2 Case 1 girl aged 17 years before treatment. Thoracic spine tomography lateral view Irregular bone structure of the bodies with rarefactions of varying size Periosteal calcifications along the anterior margins of the upper part of the thoracic spine No wedging of the vertebral bodies and no narrowing of the discs

Figure 3 Case 1 girl aged 17 years Thoracic spine a–p view Before treatment A bilateral paravertebral abscess is visible

a central radiolucent area and a paramediastinal infiltration in the left apex. On both sides, paratracheal lymph nodes were visible.

The dental status was poor with extensive and deep-seated caries and periapical rarefactions in 6 + 1,2,6

Cultures from a skin biopsy specimen and a resected rib yielded growth of actinomyces in one of the samples (type not determined)

Treatment All teeth were extracted. Cultures gave growth of Actinobacillus actinocycetem comitans and Bacteroides corrodens from 6 + 1,5 7

The patient was treated with 0 5 g dihydrostreptomycin and 2 × 2 mill. units of penicillin daily for three periods each of 8 weeks at 10-day intervals.

The patient recovered The abscesses healed, and the general condition improved steadily Weight 51 kg E.S.R. 11 mm/h.

Radiographs (April 1969) showed that the honeycomb-like structures in the *spine* and *ribs* had decreased. A periosteal bony bridge was visible along the anterior margins of the cervical bodies. Posteriorly ankylosis between the small joints of several of the cervical vertebrae had developed, so that two blocks, each of three vertebrae had formed.

Only remnants of the paravertebral abscess shadow was revealed. Lung markings normal.

As might be expected the mobility of the spine did not improve. The patient is, and always will be stiff in the neck and the upper part of the back.

Case 2 A male agricultural worker aged 42. In 1949 at the age of 24, he was hospitalized for two periods the first time with a diagnosis of endocarditis, which was treated with penicillin and streptomycin

The second time he complained of pain in the neck and the upper part of the back. As urinary cultures and inoculation into guinea pigs yielded growth of tubercle bacilli of *human* type in 1951 he was transferred to the Hospital for Extra

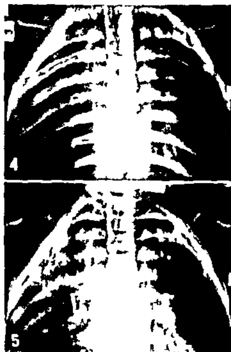


Figure 4 Case 1 girl aged 17 years Posterior part of the ribs tomography a-p view
Before treatment The medial part of several ribs shows a honeycomb like appearance and marginal serration

Figure 5 Case 1 girl aged 17 years Apices of the lungs tomography a p view
Infiltration and cavitation in the right apex A para mediastinal infiltration is seen in the left apex

pulmonary Tuberculosis Juelsminde where he stayed for a year with a diagnosis of tuberculosis of the thoracic spine the left kidney and the lungs. Gastric washings revealed tuberculosis on four occasions strangely enough of *bovine* type

Radiography of the thoracic spine showed narrowing of the intervertebral discs between Th_4 and Th_8 No collapse of the bodies but the anterior margins of Th_7–Th_{10} were irregularly eroded Large paravertebral abscess shadows were present

The Albee operation was performed at the level of the middle thoracic spine under the cover of penicillin and streptomycin

In 1954 the patient underwent at thorough course of antituberculosis chemotherapy

He then fared relatively well until 1964 when he was re admitted because a recurrent abscess had appeared in the left lumbar region Culture of pus showed growth of staphylococci but no tubercle bacilli

Radiographic of the thoracic spine showed ossification of the anterior longitudinal ligament at the involved vertebrae and a large paravertebral abscess shadow *Fistulography* through the fistulous orifice in the left lumbar region revealed entry of the contrast via the paravertebral abscess through a fistulous tract into the oesophagus

This finding did not arouse suspicion but merely confirmed the tuberculous aetiology

Medication was started with Ledercyn® and Erythromycin® later a regular course of antituberculous chemotherapy was given

As the external fistula closed in March 1966 the patient was discharged

In 1968 the patient was re admitted with a new large abscess this time in the



Figure 6 Case 2
Thoracic spine (1951) lateral view

a Narrowing of several discs Irregular anterior margins of vertebral bodies

b a-p view Bilateral paravertebral abscess

c Thoracic spine tomography lateral view (1968) Serrated periostal calcification anteriorly Reticular structure of the vertebral bodies Narrowing of several discs only slight wedging of the bodies

right lumbar region Extirpation of the abscess was performed and a fistulous tract along the internal side of the transverse processes was revealed. *Histological examination* of tissue from the abscess showed *actinomycosis* and a typical Wolff Israel actinomyces was cultivated from the pus

The patient was then given antituberculous chemotherapy for 6 months still on the assumption that the basic disease was tuberculosis The fistulae both the old and the new ones closed and have not recurred

A check up examination in May 1969 showed a clinically good condition with E.S.R. of 5 mm/h The patient was then able to work full time

Radiographs showed normal paravertebral shadows partial fusion of the lower thoracic segments and a periosteal new growth. Only a slight bulging at the site of the healed fistula at the oesophagus was demonstrated

DISCUSSION

Our first patient the 17 year-old girl had actinomycosis involving the cervical and thoracic spine ribs and the lungs and extensive dental caries probably with actinomycotic foci in the maxilla

The involvement of the spine must have been secondary to a paravertebral phlegmon whose origin was the periapical infection or the pulmonary affection.

In this patient the clinical picture was typical with stiffness of the spine and with sinus tracts to the skin. The diagnosis was secured by the demonstration of pathogenic actinomyces, biopsy with characteristic histological findings and a radiographic appearance which is typical of actinomycosis.

Actinomyces was found in only one of the many samples studied while the others yielded growth merely of the bacterial flora which usually accompanies this fungus. The explanation of this may be that previous chemotherapy had eradicated the highly penicillin-sensitive actinomyces, while the two accompanying micro-organisms are resistant to penicillin and sensitive only to streptomycin.

Whereas the first case must thus be regarded as elucidated, the demonstration of Wolff-Israël actinomyces in the second case gives rise to clinical and radiological diagnostic problems.

The second patient had for 18 years been conceived as suffering from a tuberculosis spondylitis, since tubercle bacilli had been recovered from both urine and gastric washings.

A biopsy from the *spine* with histological examination and culture of material, which would have solved the problem, was not performed.

As far as we know, co-existance of actinomycosis and tuberculosis has been described only once before (Glahn 1950).

In the light of the experience gained in our first case and by studies of the literature, we now believe that in the second case the primary disease must have been actinomycosis, which began in October 1949 with uncharacteristic symptoms. We interpret the presence of human tubercle bacilli in the urine and bovine bacilli in the lungs as a secondary infection which had gained a foothold because of the diminished resistance of the patient.

SUMMARY

On the basis of the literature a brief survey is given of human actinomycosis with special reference to its vertebral manifestations.

Two cases are reported, making the total of published cases of actinomycotic spondylitis 70.

The first patient, a girl aged 17, suffered from typical actinomycosis of the lungs, the cervical and thoracic spine, and the upper ribs with

sinus tracts to the skin The diagnosis was secured by culture of pathogenic actinomyces biopsy and characteristic radiographic findings

The second patient a man aged 42 suffered not only from actinomycosis of the thoracic spine but also from renal tuberculosis of human type and pulmonary tuberculosis of bovine type

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Department of Orthopaedic Surgery, Centralsygehuset, Naestved, Denmark.

COLLES' FRACTURE TREATED WITH MODIFIED BOHLER TECHNIQUE

M. BLICHERT-TOFT & H. KAALUND JENSEN

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In Scandinavia immobilisation of the wrist in a functional position according to Bohler's principle has hitherto been the prevailing treatment of Colles' fracture. According to this principle the wrist is bandaged in an intermediate position between volar and dorsal flexion combined with ulnar deviation. The aim is mild volar flexion in the radio-carpal joint by using dorsal pressure on the wet plaster. Mild dorsal flexion is induced at the same time in the carpo-metacarpal joint while retaining the hand and fingers in line with the long axis of the forearm. The forearm adopts an intermediate position between supination and pronation (Bohler 1953). A number of reports have been published on treatment results in Scandinavia according to this method (Nissen-Lie 1939, Hojensgaard 1945, Rosen 1947, Madsen 1949, Wiklund & Müllern-Aspegren 1956, Hölund 1957). The strictness with which Bohler's principle was applied is not apparent in all studies. A more neutral position of the wrist has been advocated in later papers (Lidstrom 1959, Frykman 1967).

After Madsen's (1949) observations there was a tendency in this country to replace the original short forearm plaster with a high encircling plaster cast so as to prevent the pronounced tendency to redislocation. However, subsequent studies concerning the guidelines laid down by Madsen failed to show correspondingly good results (Holund 1957). Moreover, since the large cast has been associated with certain drawbacks, we attempted immobilisation with a short forearm cast and sought to achieve the most suitable position for the wrist according to experimental and clinical experience reported in the literature (Mayer 1940, Bohler 1953, Mandell 1965). The method differs from Bohler's with pronounced ulnar flexion of the wrist and pronation of the forearm. As preliminary reports showed promising results

(Kaalund Jensen et al 1967) a prospective study was planned The *results of this investigation are presented in the following*

PRESENT INVESTIGATION

The series comprises 92 consecutive casualty ward patients (17 men and 75 women) with 93 fractures from January 1967 to September 1968 Only Colles fractures with dislocation were included in the study Lidström s (1959) classification of Colles fractures was used in order to achieve a differentiated evaluation of the method s usefulness with varying degrees of fracture instability

Types II A to II E were included Fracture of the styloid process of the ulna was noted in 63 per cent of the cases

II A Extra articular fracture with moderate dorsal displacement
II B Intra articular non comminuted fracture with moderate dorsal displacement
II C Extra articular fracture with total displacement
II D Intra articular non comminuted fracture with total displacement
II E Intra articular comminuted fracture with total displacement

The types of fracture in relation to age and sex are presented in Table 1 Most fractures were ascribed to falls

METHOD

All patients were treated with immediate reduction of the fracture under local infiltration anaesthesia a m Böhler Blockade of a fracture of the styloid process of the ulna was of importance in eliminating pain reactions during the procedure

Reduction of the *fracture* was undertaken in two stages (1) Disimpaction of the fracture fragments with thumb second and third finger traction the forearm pronated and the elbow in right angle flexion (2) While maintaining traction, a padded dorsal plaster splint 12 or 15 cm wide was applied and fixed with an elastic bandage from the knuckles to the plica cubiti Reduction and manipulation of the fracture in the wet plaster then followed using dorsal pressure with the thenar eminence over the distal fragment which was simultaneously supported by the other hand s vola on the hallow side The

Table 1 Age and sex distribution in 93 Colles fractures The types of fracture are in accordance with Lidström's (1959) classification

Types of fracture	15–19 years		20–29 years		30 39 years		40–49 years		50–59 years		60 69 years		70 79 years		80–89 years		Number of fractures
	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	
II A	1	1	3	3			2	4		10		13	1	3		2	45
II B							1			7		5		2			15
II C								1		2		3		2			8
II D			1				1		2	3		1		2		1	11
II I			1				1	1	1	3		1		6			14
Total	2		8		0		11		30		23		16		3		93

injured wrist was herewith immobilised with appropriate ulnar deviation i e so that the root of the thumb aligned with the forearm s radial limitation The wrist was slightly flexed and the forearm severely pronated The cast covered both the ulnar and the radial aspect of the forearm with the thumb left free

The following day the patient returned for a bandage check and instructions were given in energetic active exercises for the fingers elbow and shoulder Radiographic examination of the fracture was undertaken before and after reduction and once a week for a further 4 weeks using frontal and profile projections A sling was only used the first few days

After 4 weeks in plaster the cast was removed and the patient began exercises under the guidance of the casualty doctor or if necessary at a physical therapy clinic until satisfactory results had been achieved (Table 2)

Twelve to eighteen months after the fracture trauma 85 of the 93 fractures were given a follow up examination by the authors and radiographs were taken of both wrists One of the 8 patients not checked had died and the remainder did not wish to participate

In order to evaluate the method s suitability for more extensive use, the present series was divided into two equally large groups of similar composition with respect to the severity of the fracture One group was treated by the authors and the other in the casualty ward by the doctor who happened to be on duty at the time of the accident The doctors in question who were all experienced surgeons were all employed in the Department of Orthopaedic Surgery and carefully instructed in the procedure

RESULTS

Incidence of Ideal Reductions

In accordance with Lidstrom we chose as criteria for ideal reduction a volar angle of ≤ 90 a ≤ 2 mm shortening † as compared to the healthy side and perfect apposition between the radial and volar

In profile projection a line is drawn through the middle of the radial diaphysis and from the anterior to the posterior edge of the distal radial articular surface The angle is measured between the proximal and volar parts of these two lines

† The difference in distance between two parallel lines drawn perpendicular to the axis through the radial diaphysis on a level with the tip of the styloid process of the radius and lower joint surface on the capitulum ulnae on the healthy and injured sides.

Table 2. Physical therapy was given to 82 fractures. The period is indicated

Period of physical therapy	< 1 week	1–2 weeks	3–4 weeks	5–6 weeks	> 6 weeks
Number of fractures	17	31	19	6	9

Table 3. Number of cases in which requirements for perfect reduction were satisfied in the different groups of fracture types

Type of fracture	II A	II B	II C	II D	II F	Total
Perfect reduction	38/45	13/15	3/8	9/11	8/14	71/93
Per cent	85			60		76

cortical surfaces with 1 mm as the largest acceptable gap. Evaluated in this manner, ideal reductions were achieved in 71/93 fractures (76 per cent). See Table 3. In the group treated by the authors, ideal reduction was found in 81 per cent of the cases, and in 71 per cent of the cases treated by others. Additional manipulative reduction was undertaken with 5 patients.

Redislocation in the Radio-carpal Joint

Redislocation required a displacement of the volar angle by at least 10° and/or a shortening by ≥ 4 mm. Fourteen such cases were seen in the series (15 per cent): four in the 1st week, six in the 3rd week, two in the 4th week and two after 4 weeks. 10/14 fractures belonged to groups II C, II D and II F. 9/14 fractures redislocated after ideal reduction. The redislocation was a dorsal dipping in three cases, radial shortening only in nine cases, and a combination of the two in two cases. Rereduction was not performed, as the volar angle exceeded 10° only by a few degrees in 2 elderly women. The frequency of redislocation was about the same in the group treated by the authors and in the group treated by "others".

Early Complications

Only a few sequelae were associated with treatment. In ten the plaster had to be corrected and/or the bandage loosened the day after

Table 4. Anatomical end results (I–IV degrees) in 84 fractures in relation to comminution of the fracture and to the functional end results. One patient had a new fracture and is excluded from the table

	Anatomical end results	Types of fracture					Per cent	Functional end results			
		II A	II B	II C	II D	II E		Excellent	Good	Fair	Poor
I	No deformity	33/41	10/14	2/7	5/10	4/12	64	45	7	2	–
II	Slight deformity	6/41	3/14	3/7	4/10	5/12	25	7	11	2	1
III	Moderate deformity	2/41	1/14	2/7	1/10	3/12	11	3	2	4	–
IV	Severe deformity	–	–	–	–	–	–	–	–	–	–
	Per cent							65	24	10	1

reduction. Two developed paraesthesia, one median and ulnar and one in the ulnar area. The paraesthesia disappeared in both cases once the plaster was removed (for further comments, see the section on late results). Four women, one of them the patient with median and ulnar paraesthesia, developed post-traumatic reflex dystrophy.

Infection as the result of the administration of an inter-fragmental Böhler block was not seen. There were no pressure necroses as a result of manipulation of the fracture in wet plaster.

Anatomical and Functional End Results (Table 4)

Evaluation of the anatomical end results was based on Lidström's classification from I to IV degrees:

Degree I: Volar angle ≤ 90. Shortening < 3 mm
Degree II: Volar angle 91–100 and/or 3–6 mm shortening
Degree III: Volar angle 101–114 and/or 7–11 mm shortening
Degree IV: Volar angle ≥ 115 and/ or > 12 mm shortening

Functional end results were evaluated on the basis of the patients' subjective complaints and objective findings (Lidström 1959, Frykman 1967).

See previous footnote

Table 5 Incidence of sequelae in 85 fractures at follow up

Type of frac ture	Sequelae										
	Pain in wrist on loading and non loading	Tingling pain in innerva tion field of the median nerve and/ or the ulnar nerve	Loss of strength	Loss of finger mobility	Loss of mobility in wrist Volar/ lor siflexion 5–15 reduced	Loss of mobility in wrist Volar/ dor siflexion 15–30 reduced	Loss of < 1/3 of normal rotation	Radial deviation	Promi nence of capi tulum ulnae	Sil ver fork de form ity	Roentgenolog ical signs of post traumatic arthritis of radiocarpal and/or distal radio ulnar joint
II A	3/41	1/41	5/41	–	1/41	–	1/41	3/41	2/41	–	2/41
II B	3/14	1/14	3/14	–	2/14	1/14	2/14	1/14	3/14	–	2/14
II C	–	–	1/7	–	–	–	–	3/7	–	–	–
II D	2/10	–	2/10	–	2/10	–	–	1/10	3/10	–	2/10
II E	3/13	1/13	4/13	–	2/13	1/13	3/13	2/13	5/13	–	7/13
Total	11	3	15	0	7	2	6	10	13	0	13

1 Excellent Unrestricted wrist function No subjective complaints or visible deformity Limitation in volar and dorsal flexion not to exceed 15 No loss of strength
2 Good Unrestricted wrist function Minor subjective complaints Deformity can be accepted if subjective complaints are not associated herewith Movement limitation up to 20° and mild loss of strength
3 Fair Less satisfactory wrist function when working with a load or upon extreme movement Function otherwise retained Moderate loss of strength
4 Poor Reduced work capacity and impaired general capacity Cases with constant pain Significant loss of strength

Table 4 discloses a relative predominance of union in less than ideal positions among severely dislocated and comminuted fractures Good functional results were seen in almost all cases of union in an anatomically correct position However, very poor positions did not preclude good final results

Late Results

Table 5 provides the most important sequelae occurring in the study Only individual groups will be discussed

Gross neurological examination of three patients disclosed effects of nerve damage Two who had developed ulnar paraesthesia during the bandaging had acquired hypaesthesia in the area Mild paraesthesia in median area without motor loss was found in two patients one of whom also had ulnar hypaesthesia

Loss of strength was also registered in accordance with the principles of Lidstrom (1959) and Frykman (1967) Strength in the injured leading hand was considered reduced if strength was less than in the non leading hand Strength in the non leading hand was considered reduced if its strength was less than half of that in the uninjured leading hand

At follow up 13 patients displayed unilateral radiological osteoarthrosis in the injured wrist three in the radio carpal joint five in the distal radio-ulnar joint and five in both joints In all cases the fractures were intraarticular in the joint in question with the exception of two cases with osteoarthrosis in the radio-carpal joint where the fracture line could not be followed through the joint surface Radiographic changes comprised manifest sclerosis of joint surfaces sub-

Table 6 31 fractures with post traumatic displacement in the distal radio-ulnar joint The difference of disalignment in the distal radio-ulnar joint of the injured and the non injured wrist in relation to radial shortening is indicated in the different groups of functional end results

Post traumatic displacement in the distal radio ulnar joint indicated as the difference of disalignment in the joint of the injured and non injured wrist	Functional end results								
	Excellent			Good			Fair		
	Radial shortening								
	< 3 mm	3–6	7–11	< 3 mm	3–6	7–11	< 3 mm	3–6	7–11
+ 1 — + 3 mm	●●●●●●●●●	●●●●	●	●	●●●●		●		
≥ + 3 mm			●		●●●●	●		●●	●●●

chondral clearing and the formation of osteophytes Cases with non ideally reduced fractures and fractures with redislocation made up a large part of the group Functional end results were surprisingly good 5 excellent 5 good and 3 fair

Displacement in the Distal Radio-ulnar Joint

Displacement was found in 31 cases (37 per cent) at the follow up Displacement is an indication of secondary shortening of the radius and is measured as the difference of disalignment in the distal radio-ulnar joint in frontal radiographs between the injured and non injured wrist There was a $\geq + 3$ mm displacement in 11 (Table 6) There was good correlation between the degree of displacement in the distal radio-ulnar joint incorrect positioning after fracture union and functional results

Socio economic Status

Since most patients with Colles fracture are elderly this type of fracture is not of great interest from the insurance point of view 13/92 patients bothered to send in notices to the insurance office

At the follow up examination 75/84 patients had unimpaired work

ing capacity, 8 had mild and 1 had severely impaired working capacity. Two had to give up their previous occupations: one was a 62-year-old woman who had done heavy cleaning work, and a 21-year-old diabetic instrument maker.

DISCUSSION

Previous reports on the treatment of Colles' fracture and the results of the present study confirm that union in a less than ideal position contributes significantly to impairment of functional results. Assuming correct anatomical reduction, the usefulness of a method, therefore, depends on the related incidence of secondary dislocation of fragments.

The unstable Colles' fracture is a typical compression fracture with radial and dorsal compression of the spongiosa. Exact reduction leaves these areas with a spongiosa defect, which is why accurate radial and volar apposition of intact cortical bone should be aimed at in an effort to stabilise the fracture. The dorsal cortical bone is often shattered and therefore of little service for retention of the corrected fracture. Under these circumstances, immobilisation without the use of internal fixation is difficult to achieve without the development of redislocation.

With a view to the greatest possible stability after correction, we feel that careful and gentle reduction, preferably at the first attempt, and modelling of the fragments are of the greatest importance. Immobilisation with the forearm in pronation is recommended to correct the "supination twist" of the distal fragment as described by Mayer (1940). Ulnar flexion is used to counteract radial dipping, whereas the degree of volar flexion appears to be incapable of influencing the re-dislocation tendency (Sirbu & Collof 1951, Gartland & Werley 1951) and should therefore only be induced the few degrees necessary to create careful volar apposition.

With an ideal reduction incidence of 76 per cent when using the above principles, we achieved stable immobilisation with a redislocation incidence of 15 per cent for the entire material. Taking groups II C to E separately, 30 per cent redislocated. Mandell's material (1965), treated according to the same principles as ours, had redislocation in 20 per cent of the cases without any indication of the degree. Lidström's series, comprising 178 checked cases treated with a short dorsal slab with the wrist in a neutral position, displayed a

28 per cent incidence of redislocation for the entire material and 40 per cent for groups II C to E Redislocation occurred with Madsen (1949) in 59 per cent of the cases treated with forearm plaster and in 11 per cent of the cases immobilised by high encircling plaster with the wrist in Böhler s positión In Holund s series (1957) 40 per cent of all fractures treated with a high encircling plaster with the hand immobilised according to Böhler s principle redislocated The materials are not directly comparable as the criteria given by the latter two authors for redislocation are not exactly the same as those given by Lidstrom (1959) and the present authors However even taking this into consideration we feel our immobilisation principle with Colles fracture had considerable bearing on the low incidence of redislocation

In our opinion extension of the plaster to the upper arm provides no added advantage in view of the varying reports of redislocation when using this form of bandaging with the same fracture types and principles of treatment (Madsen 1949 Holund 1957) Furthermore an angled plaster may restrict mobilising shoulder movements (Holund 1957) which is important in order to avoid the shoulder hand finger syndrome (Frykman 1967)

Lidstrom (1959) and Frykman (1967) found that approximately 50 per cent of their patients with distal fractures of the radius had subjective sequelae at the follow up 20–25 per cent of them so severe that the results had to be reported as unsatisfactory This was the case in approximately 11 per cent of our patients one year after their accidents In this connection the high frequency of ideal reduction and low incidence of redislocation should not be reported without mention including the intensive physical therapy given during and after bandaging

Previous reports show that a disalignment triggered by trauma in the distal radio ulnar joint beyond the normal variation of ± 3 mm (Lang 1942) is often associated with pain conditions of long duration (Lang 1942 Kiaer 1949) In our material ten patients were found with significant redislocation in the distal radio-ulnar joint resulting in a disalignment of more than ± 3 mm Three of the patients had wrist pain particularly on twisting motion and seven had reduced strength 12–18 months after the fracture This number of patients with persistent pain in conjunction with level displacement in the distal radio-ulnar joint was relatively smaller than that reported by Kiaer (1949) whose patients were only observed for three months

It seems that these sequelae tend to disappear with an extended period of observation.

According to Lidström (1959) and Frykman (1967) radial shortening combined with level displacement in the distal radio-ulnar joint is an important factor in the genesis of patients' subjective complaints about the injured wrist with corresponding impairment of functional results. Table 6 confirms this observation as there is an increase in cases with relative extension of the ulna in relation to pronounced radial shortening and declining functional results. Thus the relative extension of the ulna appears to be of value in assessing functional results even if results are not unequivocal (Table 6).

The occurrence of post-traumatic arthritis which cannot be distinguished radiographically from degenerative osteoarthrosis is well known in conjunction with traumatic joint injury (Abrams 1966). Radiographic evidence may appear within 3–6 months after the triggering trauma (Abrams 1966). The development of post-traumatic arthritis in the radio-carpal joint and distal radio-ulnar joint is reported in the literature with varying frequency and time intervals (Frykman 1967). Our findings of 13 cases with this sequela radiographically evaluated as mild may suggest that this condition develops more frequently than previously believed. The unilateral localisation with development after adequate trauma supports the notion of a traumatic genesis.

SUMMARY

A prospective study of the unstable Colles' fracture treated according to modified Bohler principle is presented. A total of 92 out-patients comprising 93 consecutive dislocated Colles' fractures were treated.

The technique is described in detail and its suitability is discussed with reference to redislocation in the radio-carpal joint and displacement in the distal radio-ulnar joint during and after immobilisation. Anatomical and functional end results were evaluated 12–18 months after the injury. Union in an ideal position and good functional results occurred in 64 per cent and 89 per cent respectively of the cases. The late results were evaluated on the basis of subjective and objective findings.

The authors state that the method can be used to advantage in the treatment of the unstable Colles' fracture if the enumerated principles are adhered to.

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Department of Surgery, Children's Hospital, University of Helsinki, Finland

RECURRENT DISLOCATION OF THE HIP

Report of two children

ERKKI S. HEIKKINEN & MATTI SULAMAA

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Recurrent dislocation of a structurally normal hip is rare. Only a dozen case reports on adults and children have been published in the literature to date (Hensley & Schofield 1969). In relation to this incidence it is surprising that the Children's Hospital in Helsinki has treated two children with recurrent dislocation of the hip joint.

CASE REPORTS

Case 1 was a boy with no familial history of musculo-skeletal diseases. His birth weight had been 3450 g and the delivery had been normal. Several clinical examinations during the neonatal period and infancy recorded normal hips. The mother, however, had noted a snapping noise in the region of the hips while tending the child. The boy started walking at the age of 11 months and at 18 months he began to click his hips by placing his knees in semiflexion, crossing his ankles, and rotating them inward. He gradually learned to tease the family by the loud noises he made with his hips.

The boy was admitted to the Children's Hospital at the age of 5. Examination disclosed that he walked and ran without a limp. Hip movements were good and the tendon reflexes of the lower limbs were symmetrical. The Ortolani test was bilaterally negative but the provocation test bilaterally positive. In addition, the patient could, on request, easily dislocate and reduce both hips. The posterior and lateral dislocation of the femoral head could be heard, seen, felt and roentgenologically verified (Figure 1). Unfortunately attempts at arthrography had failed.

Treatment with various dressings and the Denis Brown abduction splint produced no result. The boy found out how to click his hips even while wearing them. All treatment was therefore abandoned. At the age of 8 the boy still continued with this bad habit but later on he gradually gave it up.

The boy is now 16 years old. His hips are stable and move normally, and roentgenologically their structure is also good (Figure 2).

Case 2 was a girl whose mother had had a bilateral recurrent dislocation of the humerus and unilateral recurrent dislocation of the knee. The girl's birth weight had been 3140 g and the delivery was by caesarean section. Clinical examinations



Figure 1 Radiograph of the hips of the boy (case 1) at the age of 5 years The right hip has been dislocated by provocation

Figure 2 Radiograph of the hip of the boy at the age of 16 years



Figure 3 Radiograph of the hips of the girl (case 2) at the age of 3 years No pathological findings could be elicited except a slight widening of the medial part of the joint space in the right hip

Figure 4 Arthrograph of the right hip of the girl at the age of 3 years

made neonatally and during infancy revealed no abnormality of the hips But when the girl began to walk at the age of 14 months her mother noticed that she limped slightly with the right leg Before the age of two the child had begun to click her right hip in bed On a few occasions the hip became locked in a faulty position and the parents had to reduce it by traction From time to time the hip was painful

The mother brought the child to the Children s Hospital for the first time at the age of 3 The girl was found to limp slightly while walking The legs were of equal length, there were no signs of muscular atrophy the tendon reflexes of the lower extremities were symmetrical and the hip movements were good Slight hyperflexibility and hyperextensibility were noted in the finger joints wrists and knees The Ortolani test of the hips was negative but the provocation test showed

onset in both cases occurred at the age of 18 months. Neither showed any trauma in the medical history, no dysplasia of the joint, no arthritic changes, no capsular defect or muscular paresis. The boy recovered spontaneously and the girl underwent operation at the age of 5.

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Orthopaedic Hospital of the Invalid Foundation, Helsinki Finland

INTERTROCHANTERIC DISPLACEMENT OSTEOTOMY IN THE TREATMENT OF OSTEOARTHRITIS OF THE HIP

Results of follow up examination

P Salenius A Langenskiöld & K Österman

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In the treatment of osteoarthritis of the hip conservative methods rarely achieve a lasting result Therefore operative treatment is often indicated especially when the patient has pain at night which disturbs sleep and impairs the general condition Since 1935 when McMurray published the results of his first intertrochanteric displacement osteotomies for osteoarthritis of the hip this method has won growing favour for early cases of osteoarthritis (Blount 1964 Ferguson 1964 Hirsch 1961 1969 Nissen 1963 1964 1966 Osborne & Jahr 1957 Ottolenghi & Frigero 1962 Lucht & Tarp 1967)

When internal fixation is carried out by using only one nail in the proximal fragment a rather high rate of non union has been encountered (Green 1967 Rosborough & Stiles 1967 Scott 1967) In recent years various compression plates and nails have been accepted in common use (Hammond & Wainwright 1967 Müller 1957 Osborne 1964 Salenius 1970)

MATERIAL

Since 1945 more than 400 intertrochanteric displacement osteotomies have been performed at the Orthopaedic Hospital of the Invalid Foundation for the relief of pain caused by arthrosis of the hip The present material includes the osteotomies performed up to the end of 1965 The total number of patients was 201 In 8 cases osteotomy was performed bilaterally making a total of 209 74 patients were men and 127 women Table 1 shows the age distribution

Table 1. Age distribution

Age (yrs)	No. pat.	Men	Women
Under 20	1	–	1
20–29	8	3	5
30–39	22	6	16
40–49	55	19	36
50–59	64	27	37
60–69	42	15	27
Over 70	9	4	5
Total	201	74	127

The mean age of patients was 51½ years. The youngest was 16, with pain in the hip following arthritis of the hip. The oldest was 77 at the time of operation. The reason for treatment in all cases was pain in the hip. Pain occurred only under strain in 66 cases, and also at rest in 135 cases. 26 patients used a stick, 5 used elbow crutches, and 56 visibly limped.

The 83 cases of secondary arthroses were unilateral except for one case. There were 35 cases of bilateral primary arthrosis.

TECHNIQUE OF OSTEOTOMY

Intertrochanteric osteotomy was performed in the usual manner. The distal fragment was always dislocated medially. The degree of dislocation varied somewhat, but because a Wainwright nail was used in most cases the dislocation became large, averaging half of one third the diameter of the diaphysis. Table 2 shows the fixation used in operation.

Table 2. Fixation of the osteotomy

Fixation	No. of hips	Non union
Wainwright nail	141	9 (6.4 %)
McLaughlin nail	27	2 (7.4 %)
Lane plate	5	
Kessel plate	7	
Other fixation	5 (Nicol 4 + Blount 1)	
No internal fixation	24	
Total	209	11

The ileopsoas was severed in 113 cases and left unsevered in 96 In the last few years discission of the ileopsoas has been a routine procedure in this operation In certain cases ligamentum ileo femorale was also deliberately discised Plaster immobilization was used with the McLaughlin nail the Lane plate and the Kessel plate and also in cases without internal fixation a total of 33 cases Plaster immobilization averaged 8–10 weeks In recent years patients have been allowed to rise from bed with the aid of elbow crutches immediately after operation but without weight bearing on the operated limb Weight bearing is allowed 6–10 weeks after operation Table 3 shows correction of position during the operation

Table 3 Change of position of fragments at operation

Chance of position	No of hips	Prim arthr	Sec arthr
Ad varus	25	17	8
Ad valgus	53	18	35
No change	131	90	41
Total	209	125	84

Non union occurred in 11 cases 9 with the Wainwright nail and 2 with the McLaughlin nail Six of these cases were re-operated and consolidation was achieved in 4 In 7 cases however follow up examination revealed non union still present at the place of osteotomy In 5 there were no symptoms however and only 2 patients had difficulties in walking In 9 cases post operative thrombophlebitis occurred but improved for the most part under medical treatment There was one mild case of cerebral insult which recovered without leaving symptoms In the post-operative phase one patient suffered a fracture of the femur on the same side Wound infection occurred in 2 cases Two patients died immediately after operation the evident cause being pulmonary embolism in both cases In 3 cases arthrodesis was later performed on the same side for relief of pain Denervation had been attempted in 2 of these cases without success

FOLLOW-UP EXAMINATION

Follow up examination was performed in spring and summer 1968 Observation period averaged 5¼ years The longest observation period was 22 years and the shortest 2½ years During the long observation period 17 patients had died from a variety of causes Two patients

could not be traced and a total of 180 came for follow up examination including 8 bilateral cases 188 hips were therefore subjected to follow-up examination

RESULTS

Table 4 shows results according to the patient s assessment

Table 4 Result according to patient s assessment

Result	No of hips	Prim arthr	Sec arthr
Good	154 (82 %)	95 (83 %)	59 (80 %)
Fair	23 (12 %)	14 (12 %)	9 (12 %)
Poor	11 (6 %)	5 (5 %)	6 (8 %)
Total	188	114	74

The results were considered subjectively good if the patient had no pain at rest These patients sometimes had pain under strain but this was very slight and caused no trouble worth mentioning The patient was often able to walk several kilometres without pain (see Table 8) Most of these patients were able to put on socks and shoes themselves (Table 6) The patient considered the result very much better than before operation Cases were considered subjectively satisfactory if there was regular pain under strain but only seldom and very slightly at rest Patients in this group considered the result better or much better than before operation Cases were considered poor if there was pain at rest and the patient regarded his condition as the same or worse than before operation In 3 such cases the condition had previously been good for several years but had then deteriorated Cases which had led to arthrodesis were regarded as objectively and subjectively poor

Table 5 shows results according to clinical and X ray examination

Table 5 Result according to clinical examination

Result	No of hips	Prim arthr	Sec arthr
Good	138 (73 %)	88 (77 %)	50 (68 %)
Fair	29 (16 %)	15 (13 %)	14 (19 %)
Poor	21 (11 %)	11 (10 %)	10 (13 %)
Total	188	114	74



Figure 1 Subluxation and severe arthrosis of the right hip of a 61 year old woman
Figure 1 A Before operation
Figure 1 B and C 3 years 9 months after operation Note the clearly visible joint space The hip is painless



Figure 2 A. The left hip of a 37 year-old man with severe arthrosis. Figures 2 B and C. The same hip 19 years 8 months after operation. After operation the patient was a postman for 17 years, now retired because of heart injury.

The result was considered objectively good if the osteotomy had consolidated in the desired position and if arthrotic changes had decreased according to X-ray examination, the joint space had widened and mobility in the hip had improved or remained the same after operation (Figures 1–4). These patients were able as a rule to put on shoes and socks, which demands relatively good mobility in the hip. 112 patients limped after operation, but this was not considered to impair the result. The result was regarded as objectively satisfactory if arthrotic changes in the hip had not increased after operation. Hip mobility in these patients was the same or better than before operation. They were not able to put on shoes or socks. The result was considered objectively poor if arthrotic changes had increased, if pseudarthrosis had developed at the site of operation, if the hip had stiffened or if arthrodesis had been performed on it after operation. Results in the secondary arthrosis group are somewhat poorer than in the primary arthrosis group.

Table 6 shows the patient's activities after operation.

Table 6. Activities after operation

	No. pat.	Per cent
Can climb stairs normally	120	67
Can climb stairs one at a time	59	33
Dresses	180	100
Puts on shoes	166	92
Puts on socks	158	88
Cuts toe nails	83	46

Mounting stairs was apparently made possible by the active flexion of the hip, which in most cases was good. The discission of the iliopsoas tendon did not reduce the strength of flexion. The outward rotation and flexion and the slight abduction of the hip are important in putting on shoes and socks and in cutting toe nails. This becomes apparent especially in cutting toe nails. In many cases the range of motion of the hip was already limited before operation, as shown in Table 11.

Table 7 shows the use of stick post-operatively. Table 8 shows walking distance after operation. The length of walking distance was estimated by the patient himself.

In estimating the patient's post-operative working capacity his earlier occupation must be taken into consideration. If the patient has had

light work before operation he hardly begins performing heavy work after operation. Also patients retired because of age hardly start working after operation even if pains have disappeared.

Table 9 shows the patient's occupation before and after operation.

Table 7. Use of stick

	No.	%
2 crutches	2	1
2 sticks	3	2
1 stick always	24	13
1 stick occasionally	50	28
no stick	101	56

Table 8. Walking distance

Distance km	No. patients	Per cent
< 1	34	19
1–3	90	50
3–5	33	18
> 5	23	13
	180	

Table 9. Patient's occupation

	Before operation		After operation	
	No. pat.	%	No.	%
Heavy work	42	23	17	10
Light work	116	65	103	57
Retired	22	12	60	33
Total	180		180	

Figure 3. Severe bilateral arthrosis of a 54 year old woman with night pain.
Figure 3 A. Before operation.
Figures 3 B and C. The same patient whose right hip was operated 4 years 1 month ago and left hip 3 years 3 months ago. Both hips are now painless.


A
B
C



A B C

Figure 4 A. Arthrosis of the right hip of a 46 year old woman.
Figure 4 B and C. The final result 3 years 4 months after operation. The patient works in an industrial laboratory.

Table 10 shows the effect of discission of the ileopsoas on results

Table 10 Effect of discission of ileopsoas on results

Result according to patient	No of hips %		Ileopsoas Divided		Not divided	
Good	154	(82 %)	96	(85 %)	58	(77 %)
Fair	23	(12 %)	14	(12 %)	9	(12 %)
Poor	11	(6 %)	3	(3 %)	8	(11 %)
Total	188		113		75	

Certain operative methods include several tenotomies such as severing the ileopsoas as was done in this material in some cases The purpose of these methods is to reduce pressure on the hip by severing the tendons of muscles near the hip In some cases pain has been relieved by the discission of adductors or ileopsoas or both separately Severing the ileopsoas in this series did not impair the flexion of the hip Most patients were able to raise the lower limb straight from a lying position Walking and mounting stairs were also unimpaired

Table 11 shows the mobility of the hip in the direction of flexion before and after operation

Table 11 Mobility before and after osteotomy

Flexion before operation	No of hips		Flexion after operation 0 –60		60 –90	
0–60 degrees	100 %	54 (29 %)	24	(44 %)	30	(56 %)
60–90 degrees	100 %	134 (71 %)	22	(16 %)	112	(84 %)
Total		188 (100 %)	46	(25 %)	142	(76 %)

Table 12 shows the effect of pre operative flexion on results

Table 12 Effect of pre operative flexion on results

Pre oper flex	No of hips	Result according to patient Good	Fair	Poor
0–60 degrees	54	40 (74 %)	10 (19 %)	4 (7 %)
60–90 degrees	134	114 (85 %)	13 (10 %)	7 (5 %)
Total	188	154 (82 %)	23 (12 %)	11 (6 %)

It appears from Table 12 that results are somewhat better in hips where pre-operative mobility was greater but the difference between results is not statistically significant

Table 13 shows the effect of the length of observation time on results

Table 13 Effect of observation period on results

Period of observation (yrs)	No of hips	Good	Fair	Poor
2–6	146	123 (84 %)	20 (14 %)	3 (2 %)
6–10	21	16 (76 %)	0 (0 %)	5 (24 %)
10–14	5	4 (80 %)	1 (20 %)	0 (0 %)
14–18	2	1 (50 %)	0 (0 %)	1 (50 %)
18–22	14	10 (72 %)	2 (14 %)	2 (14 %)
Total	188	154 (82 %)	23 (12 %)	11 (6 %)

In Table 13 cases are divided in groups according to the observation period showing subjectively good fair and poor for each group It appears that the percentage share of the various groups does not change noticeably during the observation period On this evidence the effect of osteotomy lasts for over 20 years

DISCUSSION

Follow up examination showed that intertrochanteric osteotomy is an effective means of removing pain arising from arthrosis of the hip Early mobilization of the patient obviously reduces post operative com plications Fixation of the fragments can evidently be improved still further and time of recovery and time in hospital thus shortened

In the present study no considerable differences were noticed con cerning the result of osteotomy between the primary and secondary arthrosis The differences of some per cent between the groups were not statistically significant Instead a significant difference was no- ticed between the groups where the iliopsoas was discised or not It seems evident that cutting the iliopsoas has a positive influence on the result of osteotomy and that is why this procedure has been introduced as a routine in our hospital in recent years

According to McMurray and Nissen (McMurray 1939 Nissen 1961) flexion of at least 60 90 degrees must be obtained in the hip for the results to be good This material showed a result almost independent of

the degree of flexion Differences of some per cent were not statistically significant The movement of the hip-joint was somewhat improved after operation apparently due to relief of pain In the group where the flexion was 0–60 degrees before the operation half of the patients had flexion of over 60 degrees after operation To estimate the range of movement of the hip *before operation is difficult because* in many cases pain prevents free movement On the other hand examination during anaesthesia produces flexion of the hip even to 90 degrees when sufficient amount of force is used That is why especially the pre-operative estimation of the movement of the hip is to some extent unreliable However it seems evident that a stiff hip is a disadvantage for a patient even if pain is relieved

An observation of great interest in the present material was that the effect of osteotomy had lasted for more than 20 years Previously osteotomy was often performed in advanced cases and post operative immobilization in plaster was apt to impair the result Because the results were nevertheless good in regard to the relief of pain osteotomy can be regarded as a reliable measure in the treatment of a painful arthrotic hip

If the hip is stiff and especially if both hips are stiff it seems that arthroplasty would be better indicated

CONCLUSIONS

For the operated hips pain had disappeared at rest in 154 cases (82 %) and these patients seldom had pain even on strain In addition pain had diminished in 23 (12 %) other hips Arthritic changes were observed to have diminished in the X ray to a great degree in 138 cases (73 %) and partly in 29 cases (16 %) Osteotomy is thus to be regarded as a reliable measure in the treatment of a painful osteoarthritic hip No statistically significant differences were found between the results in primary and secondary arthrosis The pre-operative flexion of the hip did not affect the result in regard to relief of pain

Discission of the iliopsoas was noted to give significantly improved results

The effect of osteotomy had lasted in some cases of the present material for over 20 years This is an observation of great importance because the effect of osteotomy can be considered to last longer than the effects of any other procedure presently in use

SUMMARY

At the Orthopaedic Hospital of the Invalid Foundation more than 400 intertrochanteric displacement osteotomies have been performed since 1945 in the treatment of painful arthrotic hip. The present material consists of the osteotomies performed until the end of 1965. Osteotomies were performed on 201 patients, 8 of these cases were operated bilaterally. The mean age of the patients was 51½ years, the oldest being 77 years of age and youngest 16 years at the time of operation. Arthrosis was considered primary in 118 cases and secondary in 83 cases. The mean observation period was five years, eight months, varying from 22 years to 2½ years. At the follow up examination the case was considered good if pain at rest and on strain had disappeared. The number of these cases was 154 (82 %). The result was considered fair if pain at rest was slight but appeared after walking. Even these patients considered their condition better than before operation. The number of hips in which the result was considered fair was 23 (12 %). The result was considered poor if pain had increased or if other operative procedures had become necessary. The number of these cases was 11 (6 %). Arthrotic changes had clearly improved radiologically in 73 % of the cases. Discission of the iliopsoas was performed during the operation in 113 cases and of these 85 % were good. In cases where the iliopsoas was not severed the result was good in 77 % of cases. This difference was statistically significant. The pre-operative flexion of the hip was not considered to have any statistically significant effect on subjective results and relief from pain. Because the longest period of observation was more than 20 years, attention was paid to the duration of relief of pain. It was noticed that of the 14 cases operated 18-22 years ago, the subjective result was good in ten cases, fair in two cases and poor in two cases. It seems evident that the effect of osteotomy may last for more than 20 years.

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Department of Orthopaedic Surgery, General Hospital, Malmö
(University of Lund)

RESTORATION OF BONE MASS AFTER FRACTURE OF THE LOWER LIMB IN CHILDREN

Bo E. Nilsson & Nils E. Westlin

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Fracture of the tibial shaft in adult man causes a loss of bone in the knee region amounting to about 25 per cent; the loss after an injury to the semilunar cartilage is about 10 per cent. *Adults seem to have* very little ability to restore the bone mass after such local loss (Nilsson 1966, Nilsson & Westlin 1970).

The objective of the present study was to measure post-traumatic osteoporosis in children in order to investigate the ability of the young child to restore the lost bone mass.

MATERIAL AND METHODS

The material consisted of 30 young adults, 18 men and 12 women, 14 of whom had sustained fracture of the shaft of the tibia and 16 fracture of the shaft of the femur. The age at the time of the fracture was 8.8 ± 3.9 years (average ± standard deviation) and the average time elapsed between the injury and the measurement was 11 years. Only cases without history of other injury or disease in the lower limbs were included.

The bone density was measured in the distal end of the femur using a photon absorption method. The attenuation of the radiation from an Americium 241 source was measured with the beam passing through the epicondylar level of the distal end of the femur (Figure 1). The bone density was calculated and expressed in g/cc of bone. The method has previously been described in detail (Nilsson 1966).

The leg length was measured from the anterior iliac spine to the

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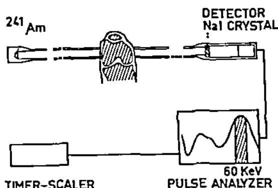


Figure 1 Measuring device

medial malleolus with a measuring tape the accuracy of this method is at the best 1 cm

In the statistical analysis probability levels of 95 per cent or better were considered significant

RESULTS

In the cases of femoral shaft fracture there was a significantly increased leg length on the injured side as compared to the uninjured the difference was 0 63 ± 0 22 cm (average ± standard deviation) There was no measurable difference in the leg length in the cases of tibial shaft fracture

There was no significant difference at the time of the follow up in the mineral contents in the distal ends of the femora between the injured and the uninjured legs of the individuals who had sustained *tibia shaft fractures* In the individuals with *femoral shaft fractures* however the uninjured side was significantly denser (Table 1)

Table 1 Changes in bone mass in the distal end of femur after fracture of the femur and the tibia
(Control minus fracture g/cc)

	No	Difference (average ± S E.)	
Tibia	14	—0 006 ± 0 009	Non significant
Femur	16	0 011 ± 0 005	Significant

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Institute for Experimental Research in Surgery, University of Copenhagen,
Surgical Department A, Frederiksberg Hospital, and Department of Plastic Surgery,
Rigshospitalet, University of Copenhagen, Denmark

BONE GROWTH IN THE FEMORAL HEAD FOLLOWING PEDICLED BONE GRAFTING

An Experimental Study

SANDOR MEDGYESI

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The common occurrence of aseptic necrosis of bone in the head of the femur following intracapsular fracture of the femoral neck—not only in the presence of non-union but also when the fracture has apparently healed—must be due to the special blood supply of the femoral head (Trueta & Harrison 1953). The supplying blood vessels are torn or thrombosed by the fracture, and the cells in the bone and bone marrow perish. The radiographic phenomena of increased density, a mottled appearance, and collapse are due partly to necrosis and resorption and partly to the new formation of bone. Reduction and osteosynthesis are followed by revascularization leading to more or less intensive new formation of bone. However, this new formation has a tendency to become arrested. The explanation is that in the course of time the dead bony tissue in the femoral head loses its inductor capacity and that the increasing number of multipotential connective tissue cells are no longer converted into osteogenic cells.

Several surgeons insert an alloprosthesis in cases of intracapsular femoral neck fracture. Others try a more physiological solution, consisting in the insertion of a live bone graft, small or large, into the head across the fracture (Judet 1963, Moyin 1966). Part of the dead bony tissue is thereby replaced by live tissue. Of course, there always remains no small amount of dead bony tissue to be revascularized and replaced by living tissue. It was the object of the present study to elucidate whether this live bone graft is able to contribute to this process.

In previous experiments on pedicled bone grafts good survival of the grafts was obtained (Baadsgaard & Medgyesi 1965 Medgyesi 1968) The ability for healing to avascular sites has also been studied (Medgyesi 1965) In this latter investigation it was suggested that the live bone graft is able to induce creeping substitution in the deeper parts of the avascular bone

METHOD

The experimental animals were mature or almost mature rabbits i e in the latter the epiphyseal cartilage was still discernible The animals were anaesthetized by Nembutal administered slowly by the intra venous route

After cutting the ligamentum teres and dislocating the head of the femur the femoral head on one side was sawn off by a rotating saw just distally to the articular cartilage in 28 cases *The pedicled graft*

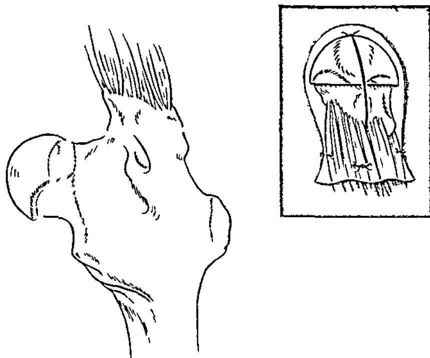


Figure 1 Graphic presentation of the operative method

was sawn off the greater trochanter of which it made up the greater part During the operation care was taken not to damage the periosteum and all the muscles attached to the graft were preserved as a pedicle The pedicle was dissected to a length of 1 cm The entirely freed femoral head and the pedicled graft were kept together by a silk ligature cancellous bone facing cancellous bone In addition the head and pedicled graft were isolated by a small hood of polyethylene foil The foil was fixed by a few superficial silk sutures to the periosteum and muscle pedicle (Figure 1) It must be pointed out that presumably it was inevitable to compromise the blood supply of the graft to some extent by the sutures

The rabbits were killed 1 days—14 months after the operation Nine received 50 μC Ca 45/kg 24 hours before being killed In these cases autoradiography was done by the aid of 200 μ thick undecalcified ground sections kept in contact with an Ilford Nuclear Research Plate G_5 50 μ For histological study haematoxylin eosin and van Gieson stainings were used In addition angiography using Micropaque filling of the blood vessels was attempted in a number of cases but without obtaining sufficient filling of the capillaries

Another 16 rabbits were treated not by a pedicled bone graft but by a muscle pedicle consisting of the muscles attached to the trochanter The femoral head was placed against the muscle pedicle so that the cancellous bone was in contact with the cut surface of the muscles Isolation was effected as described above The rabbits were killed from 4 days to 6 months later

RESULTS

The Pedicled Grafts

Half the grafts proved entirely unaffected by the separation However dead osteocytes were observed in the immediate vicinity of the sawn surface but bone cells and bone marrow cells were otherwise surviving throughout (Figure 2) Normal osteocytes osteoblasts and haemopoietic cells were present In the other half of the cases there was damage in places to the bony tissue usually of limited extent but sometimes affecting major areas The osteocytes appeared to have been most sensitive to the operation The well known signs of nuclear pyknosis were seen in the younger preparations Some weeks passed before the cells disappeared from the lacunae In these preparations there was reduced haemopoietic activity but the cells in the reticular

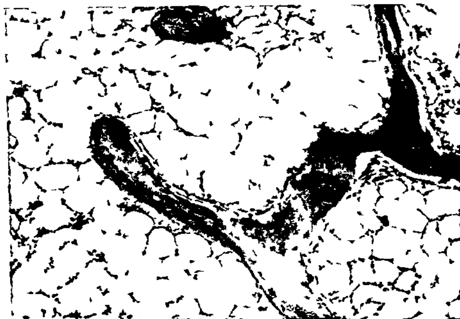


Figure 2 Live bony tissue from the inside of the graft The bone marrow is fatty in this case One month preparation

connective tissue the osteoblasts and the cellular elements of the sinusoids and capillaries looked unaffected Total necrosis of the grafts was observed in two cases These phenomena were also easily rec ognized in older preparations because there was little osteoclastic activity around the dead bony trabeculae i e they were lying *in situ* The newly formed bony *trabeculae could be distinguished from the* old ones because of their more irregular structure and often more intense basophilic staining Quite rapidly a certain new formation of bone took place in a number of the grafts subperiosteally as well as endosteally mainly in those grafts where some of the osteocytes had perished In the older preparations the bony trabeculae were thinner than normal presumably owing to inactivity

There were no changes in the muscle pedicles apart from the ac cumulation of connective tissue cells and capillary proliferation in the vicinity of some grafts

Femoral Head in Contact with the Pedicled Bone Grafts

In a one week specimen there was already a large number of cells between the two pieces of bone These cells originated partly in the

intertrabecular tissue of the pedicled bone graft and partly in its periosteum. At the outset and especially where a small haematoma had been present the cell population consisted of macrophages, lymphocytes of different size, a very few giant cells and plasma cells and occasional leukocytes. In addition there were already at that time a few cells corresponding in appearance to the histological descriptions of primitive mesenchymal cells. The term mesenchymal cells is also used in connection with bone induction (Urist et al 1967) but in this context it seems more correct to use the term undifferentiated or multipotential connective tissue cells. In the course of approximately two weeks this cell population had yielded to more regular connective tissue which continues the invasion into the femoral head together with the proliferating capillaries and gradually larger blood vessels. The entire femoral head had been permeated in the course of 2 months. Little osteoclastic activity was found. Only a few cases showed penetration of the old bony trabeculae by the invading blood vessels. It must be assumed that in most cases the blood vessels and connective tissue invaded the intertrabecular space where the original blood vessels had been. As already mentioned the epiphyseal cartilage was still present in the femoral head in some of the rabbits at the time of the operation. In these cases the tissue invasion stopped at the epiphyseal line. The epiphyseal cartilage appeared to act as a barrier *to the tissue invasion. On the outside the connective tissue grew up* along the articular cartilage and encapsulated the entire head in most cases. However the articular cartilage acted in the same way as the epiphyseal cartilage. It was very seldom penetrated despite the fact that its cells had perished.

The invading connective tissue consisted of two types, in several cases co-existing in the same preparation (Figure 3). One, the less common, was dense connective tissue with a number of fibrils and numerous fibrocytes as well as a few other cells such as macrophages and lymphocytes. This fibrous tissue was fairly avascular. The other type was a connective tissue with a smaller content of fibrils but more vascular, reminiscent of areolar or reticular connective tissue. In this tissue there were a number of the above mentioned multipotential connective tissue cells. In relation to the cytoplasm these cells had a *large vesicular nucleus which however was smaller and more rounded* than the nucleus of the fibroblasts. The cytoplasm stained faintly. The greater part of the nuclear chromatin was often of a peripheral situation and the nuclear membrane was distinct. This tissue also con

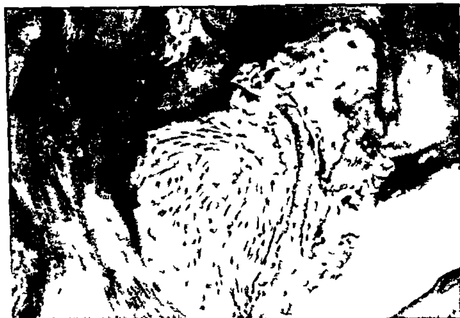


Figure 3 Loose connective tissue with newly formed bone as well as non productive fibrous connective tissue from the inside of the femoral head

tained fibroblasts and transitional varieties between fibroblasts and the named cells therefore the differentiation was often difficult In addition there were typical macrophages and other connective tissue cells The undifferentiated connective tissue cells were often seen in larger quantity in the vicinity of the proliferating small blood vessels It was in this type of connective tissue that bone formation took place in most of the cases Bone marrow formation followed only upon invasion of connective tissue of this type

Callus formed between the two pieces of bone at least before the lapse of two weeks It consisted of irregularly arranged densely placed cancellous bone Incidentally bone formation was delayed in relation to connective tissue invasion inside the preparation In preparations removed a short time after the operation this delay was about two weeks but in older preparations it was longer As already mentioned the connective tissue took two months to penetrate but in the most distal part of the femoral head bone formation did not appear until 4 months had elapsed Autoradiography gave an excellent survey of the appearance of bone formation (Figure 4) However conclusions concerning the relative quantity of newly formed bone cannot be

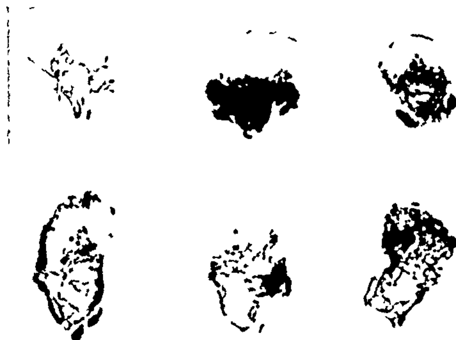


Figure 4 Autoradiography Top left a normal femoral head Thereafter a ' week 1 month 2 month 3 and 5 month preparation The pedicled grafts at the bottom

drawn on the basis of the intense blackening The autoradiographic exposures give the impression that the volume of new bones exceeds that of the old bony trabeculae in most places but this was not so In most cases the newly formed bone had settled on the old bony trabeculae i e it was a case of "creeping apposition These deposits were about 1/5 as thick as the original bony trabeculae (Figure 5) However there were instances in which major islets of woven bone or entirely new trabeculae would form

In the older preparations a return of the haemopoietic bone marrow might be seen often parallel with new bone formation This bone marrow was less cellular than normal but otherwise showed the same characteristics as normal bone marrow in the rabbit

Femoral Head in Contact with a Muscle Pedicle

No primary callus formed in these cases Only one case exhibited minimal bone formation before the lapse of two weeks In this case there was a suspicion that a few osteogenic cells had survived in the



Figure 5 The old bony trabeculae with deposits of newly formed bone At the top an independent island of new bone The photograph is from the distal part of the femoral head 5 month preparation

head itself The fact is that a few normal looking osteocytes were seen *in the immediate neighbourhood of the newly formed bone indicating* that a small area of the head had survived the grafting and had formed an ossification centre Apart from the fact that primary callus formation was usually absent the entire process was surprisingly like that seen in the experiments using pedicled bone grafts The nature of the invading connective tissue was the same as described above Invasion of blood vessels and connective tissue was followed by new formation of bone slightly delayed in early preparations and more delayed in older ones Again there were the same thin deposits of newly formed bone on the surface of the old trabeculae but there were also a few apparently detached ossification centres also like those observed previously (Figure 6)

DISCUSSION

The main object of the present study was to elucidate whether a pedicled bone graft is able to secure revascularization and new forma



Figure 6 Newly formed bone as well as bone marrow in a femoral head which has been in contact with a muscle pedicle 6 month preparation

tion of bone in a femoral head which is cut off from its blood supply In addition it was investigated how long these processes take The experiments using a muscle pedicle served as a control on the rate of revascularization and at the same time supported the induction theory

Isolation with polyethylene foil ought to guarantee that invasion of tissue could not take place from any other site than from the pedicled graft The tissue migration took place at the same rate centrally and peripherally It must be assumed therefore that the endosteal blood vessels have contributed to the process at least as much as the periosteal vessels Except in the two cases where the grafts were totally necrotic the revascularization and reossification took place in the head also in cases where major or minor quantities of dead osteocytes were seen in the grafts Apparently some of the osteocytes have been rather sensitive even to minor disturbances of nutrition which otherwise had not influenced the other tissue components of the grafts and which had not interfered with their role as a source of revascularization Tissue invasion went all through the femoral head except in the experiments where epiphyseal cartilage was still

present The explanation of the latter phenomenon must be that osteoclastic activity has been relatively slight throughout the head Newly formed bone was seen throughout but not in particularly great quantities This is in keeping with previous observations of bone formation in the human femoral head after intracapsular fractures of the femoral neck (Santos 1930) In this respect muscular inactivity presumably plays an important role The fact that the connective tissue took a couple of months to penetrate such a relatively small piece of bone may be explained by the relatively thick and densely arranged bony *trabeculae in the head of the femur In man it has* been reported that up to 2 years may elapse before the head has been completely revascularized (Phemister 1939 Scherman & Phemister 1947) To decide whether the possibly reduced resources of the pedicled grafts contribute to the revascularization and reossification being slower than would be expected the head was brought into contact with a muscle pedicled in some of the cases It was assumed that the well vascularized muscle pedicle was able to secure revascularization and connective tissue invasion of the head as rapidly as at all possible The invasion of connective tissue also involves a possibility of bone formation That the rate of invasion was the same in both events indicates that it is actually dependent upon the structure of the femoral head and a possible physiological stimulus whereas the nature of the pedicled tissue means less provided that the pedicle is well vascularized Apart from the primary callus formation the histological appearances were exactly identical and the changes took place in the same order in both types of experiment This indicates an induction process following upon the invasion of connective tissue into the femoral head At any rate it is evident that bone cannot invade from a muscle pedicle This is also indicated by the latent period between the invasion of connective tissue and of bony tissue This latent period was longer in the older preparations than at the outset of tissue

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This has been elucidated in the studies of Leriche & Policard (1926) and of Levander (1938) The multipotential cells (primitive mesenchymal cells) of the *connective tissue may be induced by bony tissue to form new bone* Some authors believe that the inducing substance is liberated by the dying osteocytes (Trueta 1963) At least lyophilized decalcified matrix contains this substance (Urist et al 1957) Bertelsen (1944) in a comprehensive study reviewed previous results on this subject and reported his own result. Since that time several admirable experiments have confirmed the induction theory (Urist & McLean 1952 Goldhaber 1961 Urist et al 1967) However there is not complete agreement as to which cells are induced (Trueta 1963) nor has the inducing substance been isolated biochemically

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County Hospital for Orthopaedic Surgery,
Sorø, Denmark.

INGROWING TOENAIL

Follow-up on 64 Patients Treated by Labiomatricectomy

POUL MOGENSEN

Received 26. v. 70

Since 1965 the treatment of ingrowing toenails in the County Hospital for Orthopaedic Surgery, Sorø, Denmark, has been the commonly used *wedge resection of the nail wall, nail, and nail bed including the matrix*. This method has been attributed to the hand surgeon Kanavel, but a review of the literature has shown that this is wrong. As early as 1886 Koenig (7) described the method in his textbook, but to whom the primary credit is due is rather obscure. In Anglo-Saxon literature it is called Wattson Cheyne's operation (Fowler 1958). Like Whitney (1967) I prefer calling the operation a labiomatricectomy, labium referring to the nail wall. The anatomy of the nail is outlined in Figure 1.

In the case of ingrowing nail a pressure necrosis has occurred distally in the nail groove with inflammatory reaction spreading into the nail wall. The condition occurs only on the toes and almost exclusively on the great toe. A number of external factors and a certain predisposition are contributory. The most important external factor is incorrect cutting of the nails. Often the corners of the nail are cut off as on the finger nails. Soft tissue then fills the corner space and when the nail grows forth in its usual width it collides with this tissue. Frequently a small spike of nail is hidden in the nail groove; during growth it burrows into the tissue. Tight shoes and stockings and abnormal positions of the toes are also contributory. Trauma to the great toe causing detachment of the nail is often followed by ingrowth when the nail starts growing again. Clark & Dillinger (1947) found the incidence to be four times higher among infantrymen than among sailors. Lake (1951) and Brearley (1958) have reported a higher incidence among young persons, and the patients often had lax soft tissue with a tendency to prominence around the nail. A less common type

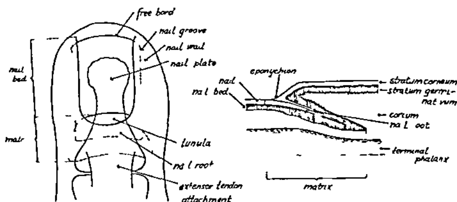


Figure 1 Anatomy of the nail nail bed and matrix

among the elderly is an increased transverse convexity of the nail so that the nail borders turn towards the phalanx This gives rise to pain and in rare cases to pressure ulceration Koppel (1968) has described the condition in a case of cartilaginous exostosis on the phalanx and a congenital abnormal inclination of the tip of the terminal phalanx

If the condition is not treated infection will supervene Gradually the infection will get chronic forming granulation tissue Heifetz (1937) divided the disease into three clinical stages First reddening and slight swelling of the nail wall and during this stage the patient is bothered mainly by pain In the second stage infection and suppuration occur The nail wall is red and oedematous In the third stage the condition is chronic characterized by granulation tissue with hypertrophy of the nail wall There are periods of flare-up with suppuration This staging appears practical The first stages may be treated with conservative measures whereas the third stage calls for operation

METHOD

Severe acute infection must be given time to subside before operation Chronic infection with granulation tissue is not considered a contra indication Our usual preparation is washing with liquid soap for 10 minutes under sterile conditions both on the day before the operation and on the day of the operation No antibiotics are administered The operation is carried out in a bloodless field and under general anaesthesia First the nail border on the affected side is

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resection of the nail wall without removal of the matrix Labiomatricectomy was performed in the remaining 66 Of these patients 3 were in the second stage the remainder in the typical third stage Operations were performed on 116 nail walls 67 on the fibular and 49 on the tibial nail wall. Five operations were done on the second and third toe all the others on the great toe Bilateral operation was performed on 11 patients In the case of 29 toes the tibial and fibular nail wall were treated simultaneously

Out of the 66 patients 27 were females and 39 males One patient was 2? months of age one was 10 years 38 were 11–20 years 13 were 21–30 years 7 were 31–50 years, 5 were over 51 the oldest 79 In 35 patients the duration of the disease was less than 6 months in 5 it was 6–12 months in 25 it was 1–10 years and in 6 the complaints had been present for more than 10 years Four patients had deformities of the nails preoperatively Two of them exhibited the above mentioned increased transverse convexity of the nail both were elderly One had onychogryposis and one had a deformity in which the nail tended to grow perpendicularly up from the toe Furthermore 5 patients were suffering from other diseases of the foot hallux valgus club-foot rheumatoid arthritis hyperhidrosis and epidermophytosis

Twenty four patients had previously been treated by ablation of the nail five of them 3 times In three of these cases small portions of the nail wall had been resected at the same time

Three operations were performed under local anaesthesia because of advanced age bronchial asthma and obesity

Postoperative Complications

Suppuration from the wound occurred in 11 patients who were then treated with chloramine dressings bed rest, and elevation of the foot, either while in hospital or at home after discharge The infection subsided in 2–14 days except in one patient who also developed symptoms from the other nail wall Another operation revealed osteitis of the tip of the terminal phalanx on this side. This patient developed symptoms of reflex dystrophy which was greatly regressing 7 months later At the sites of the labiomatricectomies the findings were satisfactory

Follow up

During the period from the operation until the present follow up study 6 patients had recurrences with the nail growing out in its entire width and giving rise to a new pressure ulceration with chronic infection Two of these patients had re operation elsewhere three had re labiomatricectomy here The 6th patient with recurrence had originally been suffering from onychogryposis and was now treated by total matricectomy by the Zadik method

Sixty four out of 66 patients were seen at follow up One had died and one refused to be examined The follow up period averaged 2? months range 4–45 months

Apart from the 6 cases mentioned above no actual recurrences were found at follow up In 17 patients a total of 22 nail spikes 1–? mm in length were found proximally at the eponychion They did not bother 14 of the patients but 3 patients said they tore their stockings There were no other complaints in particular

Figure 3 Two typical and satisfactory results following labiomatricectomy left on the tibial side right on the fibular side of the great toe



no pain Four patients had small keratotic plaques distally in the scar but they caused no trouble and could incidentally be removed with a nail brush Two of these patients also had nail spikes without symptoms (Table 1)

As to the 6 re operated patients 4 showed entirely satisfactory results one had a nail spike which tore the stocking and in one case it was too early to assess the result

Most of the patients including 4 of the re operated ones were satisfied with the result of the operation Objectively 39 i e 59 per cent showed a good cosmetic result (Figure 3) with well shaped nails and nice scars The others had rather irregular scars but without any complaints

Table 1 Results Recurrences of nail tissues in 64 patients treated with labiomatricectomy on 114 nail walls

	Number of patients	Number of nail walls	Re operation labio matricectomy	Operation by the Zadik method
Regrowth with symptoms	6	6	5	1
Nail spikes with complaints	3	3	0	0
Nail spikes without complaints	14	19	0	0
Keratin plaques	4	4	0	0

DISCUSSION

In a study of healthy police officers Lloyd Davies & Brill (1963) found that 20 per cent presented signs of ingrowing toenails This is then a common condition which in its milder forms is usually tolerated by

the patients In the present material only the most severe cases presented themselves for treatment The symptoms are derived from the pressure necrosis distally in the nail groove and complications thereof The object of treatment is to abolish this promptly and to prevent the undesired contact between the nail and soft tissues The mild cases may be managed by simple conservative measures such as thinning the centre of the nail elevating the nail corner by a cotton wool tampon or an adhesive plaster bandage (Sondergaard 1952) while the nail is growing out possibly supplemented by simple ablation of the nail On the other hand the severe cases of stage 2 and all stage 3 cases call for surgical treatment which immediately relieves the condition It was demonstrated by Quenu (1887) that removal of the matrix prevents outgrowth of the nail and this is the principle of most of the common methods (Winograd (1929) or modifications thereof by Heifetz (1957) Fowler (1958) and Zadek (1950)) Thompson & Terwillinger (1951) use total removal of the nail bed with simultaneous amputation of the tip of the terminal phalanx In the present method the nail wall and the matrix with the chronic inflammatory changes are resected Operations which remove only the nail wall cannot be recommended

In the present material there were 9 per cent recurrences with outgrowth of the nail in its entire width and a new pressure ulceration This means that the partial matricectomy has not been done and we believe that in these cases there has been a technical error for which the method cannot be blamed The patients who had re operation in the Department showed a completely satisfactory result The 17 cases with nail spikes demonstrate the difficulty of removing all the matrix tissue Even a minute remnant involves a risk of forming a nail spike On the other hand there does not seem to be any difficulty in removing the greater part of the matrix so that the nail does not grow out in its entire width as the incisions afford a good survey in the area of the matrix After injury to the nail bed there will be formation of lamellated tissue plaques differing from normal nail tissue These plaques consist of keratin (Samman (1959) Rees (1964)) The presence of these keratin plaques in 4 patients shows that the nail bed has not been sufficiently excised

The two cases of the marked transverse convexity of the nail posed no problems In advanced cases however total matricectomy is worth considering In onychogryposis the treatment is total matricectomy (Fowler (1958) Townsend & Scott (1966)) In fungal infection a specific treatment must be considered

Figure 3 Two typical and satisfactory results following labiomatricectomy left on the tibial side right on the fibular side of the great toe



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Lecturer in Veterinary Anatomy, University of Bristol, England

STRAIN IN SHEEP LUMBAR VERTEBRAE RECORDED DURING LIFE

L. E. Lanyon

Received 28 vi 70

It has been demonstrated that the mechanical response of skeletal structures varies drastically with the type of stress to which they are subjected. The response to a dynamically applied load is vastly different from that to a static one (Evans, Lissner & Pedersen 1948, Hirsch & Nachemson 1954), and the modulus of elasticity of bone as well as its ultimate yield strength are not constant (Sedlin 1965). The conditions encountered in the live animal are inevitably complex and attempts to simulate their effect on test beds without any reasonable concept of their nature are bound to produce results at best speculative, at worst misleading.

A method whereby direct measurement of bone deformation could be achieved within an ambulatory animal was first suggested by Evans (1953), although it is only recently that results from such investigations have appeared (Lanyon & Smith 1969, 1970, Lanyon 1969). Strain gauges were bonded to the bare bone surface and recordings monitored from them over a period of weeks. The reliability of this approach was first verified by attaching gauges to the tibial shaft of sheep. Subsequent work involved a series of implantations using the bodies of thoracic and lumbar vertebrae as gauge sites in the same species.

Each vertebra has a complex shape but it is the body and the arch which must be responsible for the longitudinal transmission of load. Of these the body, joined to its neighbours by intervertebral discs, is probably the more important. It was thought that a study of strain patterns in the vertebral bodies should cast some light upon the magnitude, direction and frequency of the forces transmitted along the column.

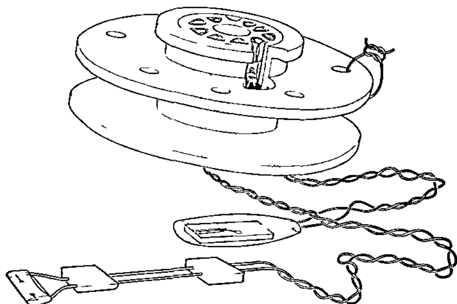


Figure 1 Schematic diagram of a gauge unit similar to those implanted during this series The gauge to be bonded to the vertebral body is shown in the foreground its lead wires passing through two epoxy resin flanges one of which was attached to the vertebral body the other to the underside of the transverse process A dummy gauge bonded to stainless steel is also shown both these are connected by the PTFE covered wires to the epoxy resin flank plug and its inserted electrical socket

METHOD

Each unit included a multi pin electrical socket embedded in an epoxy resin (Araldite CT 200 CIBA) casting so shaped as to be conveniently sutured into the skin of the animal s flank (Figure 1) This socket was connected by PTFE covered lead wires to the semi-conductor gauge element which was supported in an epoxy resin impregnated glass fibre carrier (The principle of strain gauge function requires that the strain sensitive element in this case a semi-conductor strip be attached so closely to the underlying structure that it deforms as if part of its surface This deformation causes a change in the gauge resistance which can be sensed and displayed when connected to appropriate apparatus)

The soldered joints between the gauge wires and the lead wires were protected by slightly flexible epoxy resin cast around them. (Prepot No 1 Fleming Services Cambridge) Flanges were also made of this substance and moulded round the leads just proximal to the gauge These were to be bonded to the bone to prevent any pull from the wires being transmitted to the gauge The upper surface of the gauge was covered with a layer of silicon rubber (Silcoset 100 I.C.I)

In addition to the bone bonded gauges it was usual to implant a dummy

Table 1 Overall daily average trace excursion in micr

	S 23			S 2[illegible]		
	Left side	Right side	Duration	Left side	Right side	Duration
At rest		15±7	2 4 ±0 4	9±3	28±10	1 2 ±0 7
After exercise	9±2	25±7	2 0 ±0 4	9±1	27±4	1 1 ±0 1
Slow walk	49±11	159±23	0 80±0 12	36±9	138±13	0 77±0 06
Medium walk	51±8	131±14	0 72±0 05	47±18	144±18	0 67±0 02
Fast walk	61±8	153±11	0 61±0 02	50±12	156±17	0 62±0 03
Slow trot	67±12	215±50	0 54±0 06			
Medium trot	74±18	196±25	0 51±0 02	49±9	189±25	0 48±0 03
Fast trot	81±20	223±34	0 [illegible]9±0 09			

Too small to measure
1 microstrain is 1×10^{-6} mm/mm

gauge bonded only to a piece of stainless steel Originally these dummies were used to assess whether there were any factors arising from *in vivo* implantation which could cause alteration in gauge resistance unconnected with deformation The absence of such factors had been established many times but the dummy gauges provided a useful check on equipment under certain circumstances

The vertebral bodies were reached by retroperitoneal dissection after making a vertical flank incision through the skin and abdominal muscles Adhesive solution (isobutyl 2-cyanoacrylate monomer Ethicon Ltd) was placed on the underside of the gauge and flanges which were then speedily pressed into position on the previously prepared site The wound was closed and the flank plug sutured into the skin incision The whole unit of gauge wires and flank plug had been sterilised prior to implantation by a low temperature steam and formaldehyde process (Alder et al 1966)

Each animal had been trained previously on a moving platform conveyor belt machine Although lame for one or two days postoperatively they recovered remarkably well and seemed to walk and trot perfectly soundly by the third or fourth day

When recording the implanted gauges were connected via the socket in the animal s flank to transducer meters (C 52 Boulton Paul Aircraft) with a 1 k cycle/sec carrier frequency whose D C output was transferred to an ultraviolet recorder (5–127 Bell & Howell) As the animals moved on the conveyor belt recordings of the strain change patterns during their various activities were taken This was done daily for some two weeks after which the animals were killed

rain and duration in seconds during various activities

S 28			S 29		
Left side	Right side	Duration	Left side	Right side	Duration
17±4	17±5	2 4 ±0 4	11±3	21±6	2 7 ±0 5
21±2	24±3	2 4 ±0 4	15±3	26±6	2 3 ±0 4
115±17	296±27	1 07±0 04	48±9	163±15	0 93±0 04
133±18	268±23	0 87±0 05	58±8	173±14	0 82±0 04
150±27	281±31	0 74±0 02	79±12	227±22	0 71±0 02
216±27	487±60	0 55±0 02	90	216	0 52

Satisfactory on one day only

the vertebrae with their attached gauges dissected out and these tested to ensure that there was good adhesion between gauge and bone and a faithful response to externally applied loading

A purely qualitative assessment of reliability was made by imposing lateral, dorsal ventral and axial compression on the isolated vertebrae to establish that the strain response indicated by the gauges conformed to the expected pattern The quantitative results quoted (Table 1) were calculated on the premise that the gauge bone bond was perfect and that gauge deformation accurately represented bone deformation Thus the results are certainly comparable from animal to animal given the same conditions of bonding but it has not been proved that the quantitative assessments of strain values are an absolute measurement of *in vivo* bone deformation they may only represent the maximum strain possibly transmitted by this bond

RESULTS

Eight gauges were attached to the bodies of lumbar vertebrae in four sheep (S 23 S 25 S 28 S 29) The gauges were bonded to either side of the same or adjacent vertebrae at two operations separated by three or four days This allowed for full recovery and enabled traces to be obtained during locomotion from the first gauge before the second was implanted

The animals were exercised daily, recordings of strain change patterns being taken from both gauges simultaneously during the various activities. Loading of the vertebral column is likely to be affected by many factors, some unobservable and many, such as movements of the head, which although obvious are difficult either to quantify or record. However, to allow comparison between results from different animals it was necessary to have some data on their behaviour at the time. Despite the inadequacy of recording only respirations when the animal was standing still and limb movements during locomotion, it was obvious that there was a close correlation between these and the strain change patterns obtained. Respirations were recorded manually with an event marker, thus indicating the approximate occurrence and duration of inspiration and expiration. Slow motion cine film (64 frames per second) was taken during locomotion and later studied frame by frame.

The strain change patterns occurred in obvious cycles repeated with every respiration or stride. The quantitative results (Table 1) were obtained by measuring the total excursion of each of these. This movement, in fact an indication of the change in gauge resistance, could be expressed in microstrain using the known relationship between this and gauge deformation.

Traces obtained from all four animals during respiration showed a similar pattern which consisted of a fairly sharp compressional period at the beginning of inspiration, with a subsequent tensional recovery which merged into a period of slow strain change during observed expiration (Figure 2). Eructation, bleating, coughing or any other movement completely obliterated this regular pattern. In general the traces from the two sides were perfectly in phase although recordings from *S 23* at times showed some dissimilarity producing an out of phase response. However, some facets of the locomotory results from this animal were equally at variance with the norm of the other three and perhaps therefore, although interesting, this idiosyncrasy should not be pursued. After exercise the cyclical pattern remained similar and the rate and depth of respirations were naturally increased with a consequent increase in the frequency and level of bone strain recorded. The animals were not forced and they were not panting when these recordings were taken. In general the strain change recorded from the gauge on the right side indicated greater deformation than that on the left (Table 1).

The two gaits studied on the moving platform were the walk and

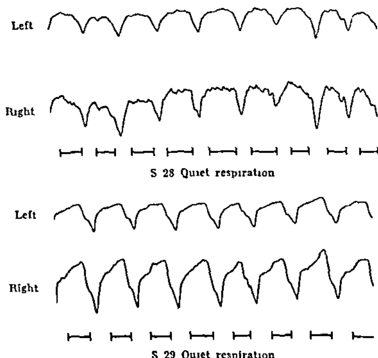


Figure 2 Part of the recordings of strain change patterns obtained from S 28 and S 29 when standing still The duration of expiration as observed from the abdominal wall and manually marked with the event marker is indicated by the solid line beneath the various traces In each case the trace from the left gauge is uppermost tension is indicated in an upward position compression downward The period of slow strain change coincided with observed expiration the compressional movement with inspiration and the subsequent tensional recovery merged with the slow strain change period

the trot The patterns of support inferred from the slow motion films are shown beneath the relevant recordings (Figures 3 and 4) and allow comparison between animals A normal quadrupedal walk consists of diagonal and ipsilateral support phases separated by intervening triangular ones These become shorter as the pace increases until the animal breaks into a trot which is a sequence of alternate diagonal supports The inevitable irregularities of gait even using trained animals walking in a straight line are evident During free natural locomotion they must be far more profound It was assumed for convenience that a limb bore no weight once the sole of its foot could be seen lifting

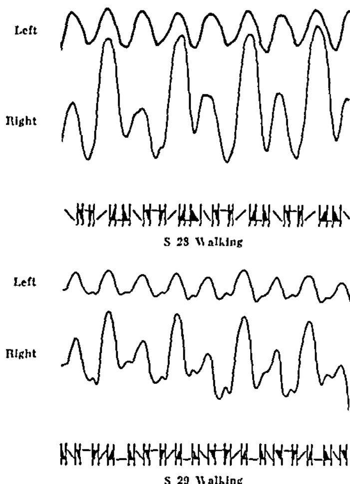


Figure 3 Part of the recordings of strain change patterns obtained from S 28 S 29 while walking on the moving platform In each case the trace from the left is uppermost tension is in an upward direction and the pattern of support is shown beneath The similarities in trace conformation and its relation to support can be seen

The comparison of trace conformation with support pattern revealed considerable similarities between animals In general during the wall triangular support phases with one hind foot off the ground led to ipsilateral support periods during which compression occurred Triangular support periods with one fore foot off the ground led to diagonal support periods and during these tension occurred Thus for each complete stride consisting of two diagonal two ipsilateral and four intervening triangular support periods there were two tension

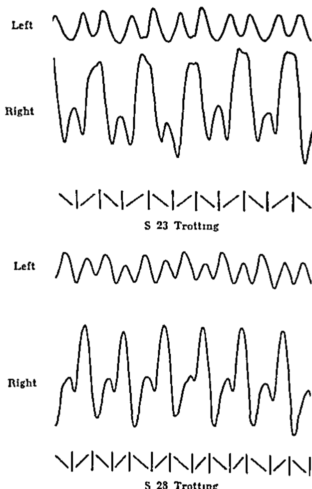


Figure 4 Part of the recordings of strain change patterns obtained from S 23 and S 28 during trotting The similarity between animals was most evident at this simple gait

compression peaks On the left side these tended to be of equal size whereas on the right side one was much larger than the other the dominant tensional phase occurring during the diagonal support period involving that hind limb The total trace excursion or strain change was always larger on the right side than the left For S 25 although there was the same large discrepancy in size between total strain change indicated on the two sides the trace conformation was more similar from one side to the other there being a large period of tension

during the diagonal support involving the hind limb of the side concerned and a small period during the opposite diagonal period

The unexpected appearance of any discrepancy in strain change pattern and shape between two sides of the same or adjacent vertebrae caused us to suspect the validity of the experiment It was thought that perhaps walking on the treadmill induced some asymmetrical emphasis which would be eliminated if they were allowed to walk free or loosely led on a halter Having the animals attached by long trailing wires was not feasible so a small radio transmitter was constructed which allowed transmission of information from one implanted gauge at a time when the animal was walking or trotting on the ground uncluttered by any impedimenta except a small package strapped to its back (Lanyon in preparation) This only confirmed the findings already mentioned while emphasising the difficulty of achieving regular results from an animal moving freely or loosely led

The vertebrae concerned with their gauges still attached and undisturbed were tested post mortem to establish the reliability of the bone gauge bond

Whereas axial compression resulted in a very small deformation for a large load asymmetric loading or loading the articular processes could result in large deformations say compression on one side with a small tensional change on the other By loading asymmetrically just with the hands—usually through the two adjacent bones to maintain the skeletal unit as intact as possible—it was easy to reproduce the size of signal recorded during life

DISCUSSION

The use of strain gauges bonded to skeletal components yields information directly that would otherwise be unavailable However its value is limited being only applicable to deformation in one direction in the small piece of the surface of the structure to which the strain sensitive element is adherent The stress distribution within a vertebra is reflected by its complex shape thus a small number of gauges cannot yield sufficient data to do more than provide a limited picture of probable loading conditions the nature and origin of which remain speculative

It has been confirmed that bone is a plastic structural component deforming under comparatively light loads both *in vivo* and *in vitro* The delicacy of the skeletal response to apparently small changes in

direction or magnitude of these is striking and indicates the great gulf that exists between the natural mechanical environment of skeletal components and that to which they are subjected in laboratory tests The discrepancy found between longitudinal strain measured on the two sides of a single vertebral body was previously unsuspected al though possible sources of asymmetry in the region are easy to find

Only a small difference in the direction of stress on the two sides would be necessary to produce a large effect in terms of the strain change patterns recorded Post mortem tests indicated that end to end compression of the vertebral bodies elicited a larger response from the right side than the left If the loading of the two sides had been dif ferently aligned during life one would have expected some adaptation to minimise deformation in the direction in which it occurred

Although specific findings such as those mentioned are interesting the significance of this type of experiment lies in the verification of a technique whereby the frequency and order of strain which bone undergoes during various activities may be evaluated Appreciation of these normal strain limits is of considerable importance in any study of osteogenesis since it seems increasingly likely that electrical activ ity possibly the result of such intermittent deformation provides one of the more important stimuli to bone growth regeneration and modelling

The concept of a normal constant reasonable strain level and frequency maintaining the architectural status of bone fits well with existing knowledge of events occurring when it would be expected either to be exceeded or not attained Once this level has been estab lished in ambulatory animals the way is paved for determining by relevant dead tests the possible origins and dimensions of the loads involved Thus the service conditions of prostheses and the funda mental properties of bone may be assessed within realistic limits and not arbitrarily chosen ones

CONCLUSIONS

A series of experiments was performed attaching strain gauges to either side of the bodies of the same or adjacent lumbar vertebrae in sheep as part of a regional mechanical survey of the vertebral column The results showed extremely similar strain change patterns between the different animals during respiration and locomotion at various speeds They also showed that the two sides of the vertebral column

seem to be subjected to loads which differ in size or orientation On the evidence from these animals it was considered unwise at this stage to attempt any detailed analysis on the origin of the loads involved

These experiments which demonstrate the reliability of a technique allowing direct instrumentation of areas of the skeleton are capable of threefold exploitation

Firstly to gain detailed information on the mechanical environment of specific areas pinpointed by clinical experience

Secondly, to allow study of one of the fundamental stimuli for bone development and remodelling

Thirdly by establishing the working environment of skeletal structures to allow these and their prosthetic replacements to be tested under realistic conditions

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Orthopedic Hospital Copenhagen Denmark

BONE FORMATION AND RESORPTION IN CASES OF DELAYED UNION AND PSEUDARTHROSIS

H Bohr

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In failure of fracture healing one usually distinguishes between delayed union and pseudarthrosis According to McLean & Urist (1955) spontaneous healing may occur until 18 months after the fracture but following this time they use the term non union implying that the process of healing has stopped On the other hand it has been emphasized (Watson Jones 1955) that almost any fracture will ultimately heal if adequate immobilization is accomplished

Previous investigations have shown that the uptake of radioactive calcium phosphate and strontium around a fracture is the same in normal and delayed union (Karsher 1953 Bohr 1955 Wendeberg 1961) indicating that the process of mineralization continues despite the failing consolidation In order to illuminate this question further the rate of bone formation and bone resorption has been studied in cases of delayed union and pseudarthrosis through microradiographic investigations and the uptake of Tetracyclines at the fracture site

MATERIAL AND TECHNIQUE

During operations for delayed union or pseudarthrosis biopsies were made from the un united bone fragments In 31 cases the material obtained was sufficient for studying the healing process These include 28 fractures and 3 osteotomies as seen in Table 1 there were also 2 cases of congenital pseudarthrosis of the tibia in children 4 and 5 years of age All cases except a fracture of the malleolus medialis, had previously been treated with osteosynthesis without success. Labelling with Tetracycline was performed before the operation in 14 cases using Ledermycin (demethyl-chlor tetracycline) Terramycin (Oxytetracycline) or Reverin (Pyrrolidino-methyl Tetracycline) In 6 cases labelling was repeated with an interval of 2–4 weeks

The bone samples were embedded in methyl metacrylate and after cutting with

Table 1 31 fractures and osteotomies in 29 cases of delayed union

Fractures							Osteotomies
fem	tib	mall	hum	uln	rad	clav	subthroch fem
4	8	2	2	5	5	2	3

a rotating saw and grinding under water bone specimens with a thickness of about 50 microns were obtained For microradiography a Machlett 50 AEG X ray tube with a wolfram anode generated at 12 kV with 12 mA was used exposures being made on Kodak spectroscopic plates 549-0 during 10 minutes at a focus film distance of 15 cm Examination of fluorescense in ultraviolet light was made with the use of Reichert filters (C 9/1 mm and OC 1/5 mm In some cases specimens were prepared for ordinary histological investigation after further grinding to 20 micron thickness and staining with Haematoxylin and Eosin following pretreatment with Mollifex and organic solvent from the British Drug House Ltd

Measurements of the surfaces of bone formation and bone resorption on microradiographs were performed with a map measurer on diagrams drawn during microscopic observations according to Jowsey et al (1965) The area of bone formed between double labelling was determined with a planimeter (OTT type 30011) on drawings during fluorescent microscopy

RESULTS

Measurements of surfaces of bone formation and bone resorption on microradiographs are given in Figure 1 as per cent of the total bone surface within an area of about 10 mm² It is seen that the extent of bone formation surfaces varied from 10 to 65 per cent and that of the bone resorption surfaces from 5 to 53 per cent with average values of 34 and 15 per cent respectively These figures are increased in comparison with similar measurements on normal adult human bone but in the two cases of congenital pseudarthrosis measurements differed only little from normal values of that age (Jowsey et al 1965) In Table 2 the average values of bone formation and bone resorption surfaces in the 13 cases where union was delayed from 7 to 18 months have been compared with the average values in the 16 cases where union was delayed from 18 to 63 months the mean age for the cases in the two groups being almost equal It is seen that there was no significant difference as regards bone formation surface whereas the bone resorption surface was somewhat greater in the last group Figure 2 shows a microradiograph from a radial fracture with a 2 year healing delay Bone formation and bone resorption surfaces

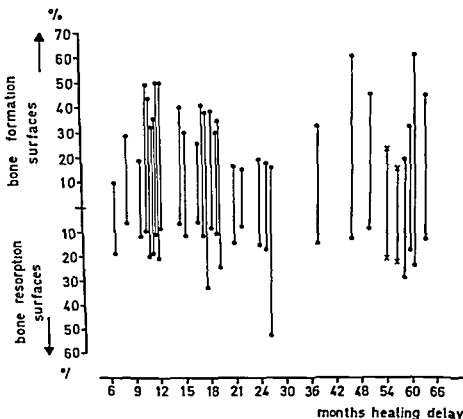


Figure 1 Measurements of surfaces of bone formation and bone resorption on microradiographs expressed as per cent of the total bone surface Results in cases of congenital pseudarthrosis are indicated as crosses

of secondary bone are increased and callus formation as indicated by the presence of primary bone tissue which is gradually transformed into secondary bone The increased osteogenic activity is confirmed from the results of the uptake of Tetracycline showing extensive labelling of bone surfaces at the bone ends In Figure 3 which *corresponds to Figure 2 it is seen that Ledermycin is deposited in* sharp lines along the mineralizing surface of the secondary bone while the primary bone tissue is diffusely labelled By repeating the administration of Tetracycline the bone tissue deposited during the interval between labellings is demonstrated (Frost et al 1960 Sissons & Lee 1964) This is shown in Figure 4 from a femoral osteotomy with a 19 month healing delay where labelling with Ledermycin was per-

Table 2 Average values of bone formation surface and bone resorption surface expressed in per cent of total bone surface in 2 groups with delay of union from 7 to 18 months and 18 to 63 months respectively

Delay in union	Number of cases	Mean age	Bone form	Bone resorp
7–18 m	15	40	37±4 %	11±2 %
18–63 m	1[illegible]	4[illegible]	32±4 %	19±3 %

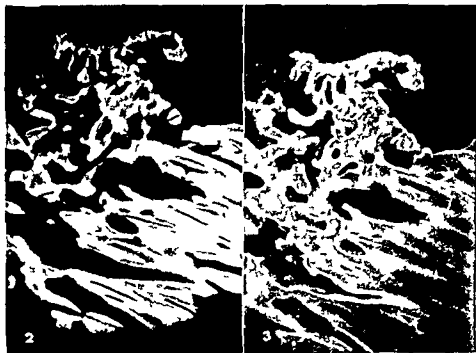


Figure 2 Microradiograph from an un united radial fracture of 2 years duration (case 253) Secondary bone with increased formation and resorption is seen below and primary bone under gradual transformation into secondary bone above Magnification × 30

Figure 3 Fluorescense photo corresponding to Figure 1 Labelling with Ledermycin was performed one day before the biopsy Sharp fluorescent lines are seen along the mineralizing surfaces of the secondary bone and diffuse labelling of the newly formed primary bone Magnification × 30

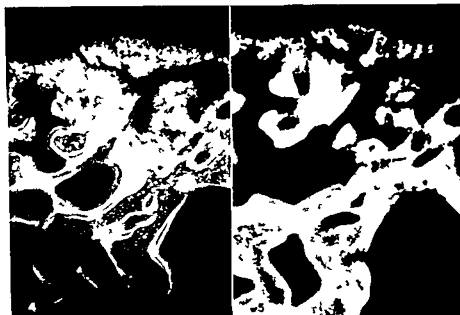


Figure 4 Fluorescense photo from an un united femoral osteotomy of 19 months duration (case 254) labelled with Ledermycin 30 days and 16 days before the biopsy Double labelling of secondary bone is seen
Magnification × 120

Figure 5 Microradiograph corresponding to Figure 3 showing calcified cartilage above the primary bone tissue
Magnification × 120

formed 30 and 16 days respectively before the biopsy Measurements of the area of bone between the corresponding fluorescent lines show the amount of bone deposited pr day to be 0 7 per cent of the total bone area and the appositional rate 1 pr day Measurements in a case of congenital pseudarthrosis showed the same bone formation rate while the appositional rate was 3 3 pr day

From the microradiograph on Figure 5 which corresponds to Figure 4 it is seen that calcified cartilage is present above the primary bone indicating that enchondral ossification takes place at the bone ends This is further demonstrated in Figure 6 from an un united femoral fracture of 5 years duration showing the typical arrangement of hypertrofic cartilage cells in columns By employing polarization microscopy the fibrillar structure of the cartilage between the bone

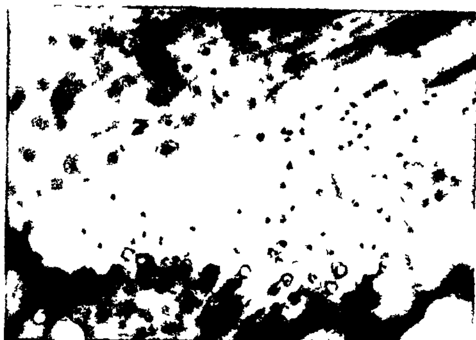


Figure 6 *Undecalcified section from an un-united femoral fracture of 3 years duration (case 251) stained with Haematoxylin and Eosin after pretreatment with Mollifex (B D H) The arrangement of the hypertrofic cartilage cells in columns indicate enchondral ossification*

Magnification × *120*

fragments is demonstrated and seen radiating from the bone surface between the cartilage cells and deviating along the fracture gap as demonstrated in Figure 7 from an un-united tibia fracture of 2 years duration

DISCUSSION AND CONCLUSIONS

Different histological methods have been used to determine bone formation surfaces Measurements of the bone surfaces covered with osteoid tissue in normal adult human bone have shown values of about 5 per cent (Sissons et al 1967) results which are consistent with the measurements of bone formation surfaces performed on microradiographs as well as with Tetracycline labelling (Jowsey et al 1965) Through double Tetracycline labelling the appositional rate has been measured and from that also the rate of bone formation (Frost



Figure 7 Polarization microscopy from an un united tibial fracture of 2 years duration (case 2?7) showing the fibrillar structur of the cartilage radiating from the bone ends and deviating along the fracture gap Magnification × 120

et al 1960 Amprino & Marotti 1964 Sissons & Lee 1964) For normal human ribs the amount of bone formed pr day was determined to be about 0 05 per cent of the total bone mass in adults and 0 1 per cent in children (Frost 1969) The appositional rate showed values of about 1 pr day in adults and 1 5 pr day in children (Lee 1965 Frost 1969)

In the present investigation the results although subject to some variation seem sufficient to demonstrate that the rate of bone formation is increased in cases of delayed fracture healing and do not decrease with time at least not within the first 5 years In the case of congenital pseudarthrosis bone formation rate was also increased although less markedly compared with normal values of that age (Skou Andersen et al 1968) The retained osteogenic activity is in accordance with the well known effect of the Phemister operation in promoting healing of pseudarthrosis when contact between the fragments is obtained through bone transplants (Phemister 1947) As spontaneous healing does not take place despite the increased bone

formation it is probably not due to the simultaneous increase in bone resorption since this was relatively small compared with the increase in bone formation The presence of enchondral ossification demonstrated suggests that proliferation of cartilage cells takes place between the bone ends The ossification of cartilage requires participation of blood vessels (Trueta 1963) and if penetration of capillaries is inhibited as in the case of ineffective immobilization (Rhinelander et al 1968) the cartilage will remain as a barrier similar to the condition existing in the epiphyseal plate of the growing bone While the proliferation of cartilage cells in the epiphyseal plate results in growth the more limited phenomenon in pseudarthrosis causes sclerosis and broadening of the bone ends Such a view seems to be supported by the favourable effect of compression forces on the healing of pseudarthrosis without interfering with the intervening tissue (Muller 1966 Witt & Jäger 1966 Mouritzen 1970)

SUMMARY

The rate of bone formation and bone resorption has been studied through microradiographic investigations and Tetracycline uptake in cases operated upon for delayed fracture healing and pseudarthrosis It was increased compared with normal bone and on the average the rate of bone formation was almost the same in the cases where union was delayed from 7 to 18 months as from 18 to 63 months while bone resorption was somewhat more pronounced in the latter group The presence of enchondral ossification suggests that the delay in healing may be due to a continued proliferation of cartilage cells between the bone ends

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Institute of Experimental Research in Surgery University of Copenhagen and the Orthopaedic Hospital Department I Copenhagen Denmark

TRANSPLANTATION OF CALLUS INVADED KIEL BONE TO DEFECT PSEUDARTHROSES

An Experimental Study

K. Baadsgaard

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In a previous study (Baadsgaard 1970) involving the transplantation of cancellous Kiel bone to experimental pseudarthroses on rabbits bone formation was rarely found in the Kiel graft on a level with the defect pseudarthrosis whereas fairly brisk ingrowth of newly formed bone was observed where the graft was in satisfactory contact with living bone of the recipient

This finding has been reported several times before For instance Orell (1937) implanting os purum which accurately corresponds to a Kiel bone obtained marked ingrowth of callus into this bone He called a callus traversed os purum an os novum and used this material for bone grafting on the same indications as fresh autologous bone grafts Maatz & Bauermeister (1957) studying the Kiel bone by Maatz spongiosa test found that the cancellous Kiel grafts were completely traversed by callus just as quickly as were the fresh autologous grafts The same finding was made by Karges et al (1963) using another type of processed heterologous bone

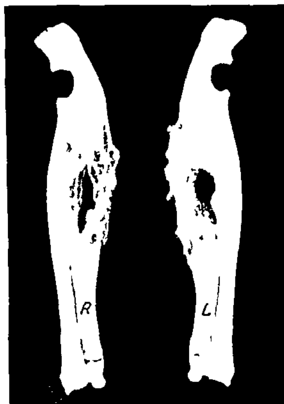
The purpose of the present study was to investigate to what extent cancellous Kiel bone implanted subperiosteally will be invaded by callus and to ascertain the properties of the os novum thus produced when grafted on defect pseudarthroses

METHOD

The experimental animals were 21 rabbits of mixed race full grown or almost full grown aged 6–12 months All the rabbits were subjected to two operations

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Figure 1 6th week X ray of the specimens L os novum R iliac bone graft Both grafts show solid union



At the first operation a defect pseudarthrosis 0 75 cm in length was produced on both ulnae 3 5 cm distal to the tip of the olecranon process by a technique already described (Baadsgaard 1970) Moreover a graft of cancellous Kiel bone 4 × 0 4 × 0 3 cm was implanted subperiosteally on the left femur

The second operation was performed 6–11 weeks later The osteosynthesis material was removed from the pseudarthrosis on the left ulna The Kiel bone was chiselled off the femur A biopsy specimen was removed for histological examination and the remaining 2 5 cm were placed as an on lay graft on the side of the pseud arthrosis facing away from the radius so that it just reached healthy bone at both end A thin polyethylene plate was inserted between the radius and ulna so that ingrowth of callus from the radius was prevented On the right a control experiment was performed using a graft 2 5 × 0 3 cm from the ala ossis ilii full thickness of bone (Figure 1)

Infection occurred in 3 cases on the right The autologous grafts from these cases were not included in the material which thus comprises 21 os novum grafts and 18 autologous cancellous grafts

T days before the rabbits were killed they were injected intravenously with ^{45}Ca 200 microcuries and intramuscularly with 100 mg tetracycline The specimens were divided transversely The proximal half was used for conventional histological

examination and the distal half for undecalcified ground sections embedded in methyl metacrylate and sawn transversely. Three cross sections of the graft on a level with the defect and one from a more distal site containing graft as well as the distal recipient site were investigated. The sections were ground down to 80 μ and studied by autoradiography, microradiography, and fluorescence microscopy. Quantitative determination of the ^{45}Ca uptake was done as described previously (Baadsgaard 1970 a, b).

RESULTS

Biopsy from Os Novum Removed Prior to Grafting

Infection did not occur in any case around the implanted Kiel bone which was always found to have become fixed to the femur. In many instances there was bone growth around the graft so that it had to be chiselled or sawn off the femur. New bone formation was seen in exceptional cases on the superficial surface. A few grafts fractured during the removal but the majority in a way so that it was possible to obtain a piece of sufficient length to cover the pseudarthrosis. On two pseudarthroses, however, the grafting had to be done with a fissured graft of os novum. At the histological examination of the novum biopsies all the specimens were found to be fully vascularized and invaded by connective tissue. Six implants had been completely traversed by callus, whereas in one case there was no ingrowth at all (Table 1). The implants had been *in situ* for periods between 6 and 11 weeks. There was no correlation between their age and the degree of callus invasion. Callus formation invariably appeared to issue from the femur invading the Kiel bone by creeping apposition. The new bone was found both as a layer directly on the trabeculae and in the cavities within the cancellous Kiel bone (Figures 2 and 3).

Table 1. Ingrowth of callus into the implants on the femur

	Callus invasion per cent	Average age days
10 implants	75–100	59
6 implants	0–20	60
Total average	60	58

Areas with new bone formation incidentally contained ample bone marrow but the remaining part of the biopsy had been traversed

Figure 2 9th week Biopsy from the Kiel bone implant Ample ingrowth of callus into the central part × 56

Figure 3 9th week Detail from same preparation as in Figure 2 × 140

after the 6th week there is a tendency for the formation of a medullary cavity, the grafts thus assuming the shape of long bones. At the same time considerable osteoclastic resorption of the necrotic elements takes place, so that the *original iliac bone graft can hardly be recognized*. Resorption of the Kiel graft is somewhat slower, but in the oldest specimens it is difficult to discern the iliac bone from the novum graft.

The results of the quantitative determination of ^{45}Ca are shown in Table 2. The mean for the os novum grafts is 153 counts/min as compared with 134 counts/min for the autologous cancellous grafts. Four os novum grafts and two iliac bone grafts with no or negligible callus gave mean counts of 43 c/min and 40 c/min.

The quantity of callus included in the graft appears to determine the effect of the os novum grafts. Thus, the result for the six grafts in which the callus content of the Kiel graft was less than 20 per cent was 70 c/min, whereas the mean for grafts with a 50–100 per cent callus content was 188 c/min.

DISCUSSION

The explanation why in some cases the Kiel bone grafts on the femur showed a disappointingly slight invasion of callus is presumably to be found in the operative technique. For mechanical reasons the grafts had to be made rather large as compared with the dimensions of the femur, so that the periosteum had to be stretched tightly over them. This may have reduced bone formation from the periosteum. Furthermore, *the grafts were not fixed to the femur. A greater and more* constant ingrowth might presumably have been obtained by subcortical implantation in the iliac crest. However, this is difficult to practise on rabbits. Likewise, it would have been difficult to obtain pure os novum grafts without admixture of the iliac bone for the grafting experiment.

In assessing the results, it must be taken into consideration that the cross section of the Kiel bone was somewhat larger than that of the iliac bone graft, but in return only 60 per cent of the implant was invaded by callus. It is difficult to measure accurately the area of necrotic callus included in the graft on the undecalcified ground sections from the end of the experiment, since necrotic and live callus are so intimately mixed. Thus, the quantity of transplanted callus could not be determined on the sections used for the quantitative

determination of ^{45}Ca Nevertheless it is possible to estimate with reasonable certainty that the active part of the os novum graft was of very much the same size as the iliac bone graft Thus the two types of grafting material showed an equal osteogenetic effect

Hellstadius (1942)) in os novum experiments on rabbits found numerous surviving osteocytes in the grafts Urist & McLean (1952) also found surviving cells on autologous grafting of fibrocartilaginous callus to the anterior chamber of rabbit eyes These findings could not be confirmed in the present experimental series in which all osteocytes disappeared from the grafts Possibly osteoblasts and connective tissue elements survive peripherally in the graft This cannot be definitely decided in autografting

SUMMARY AND CONCLUSION

Cancellous Kiel bone was grafted subperiosteally on rabbit femora When removed 6–11 weeks later the implants showed 60 per cent ingrowth of callus

The callus invaded Kiel bone was transplanted as an on lay graft on the defect pseudarthrosis on one ulna of the same rabbit whereas the other ulna was grafted with fresh autologous cancellous bone

The specimens were investigated radiologically histologically and by fluorescence microscopy and quantitative determination of new bone formation was performed by ^{45}Ca

The two types of grafting material behaved in the same way with respect to revascularization union and callus formation Neither was found to contain surviving osteocytes

It is concluded that the osteogenetic effect of callus invaded cancellous Kiel bone and fresh autologous cancellous bone is the same

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Department of Rheumatology and Department of Orthopedic Surgery
University Hospital Lund Sweden

PYROPHOSPHATE SYNOVITIS

Crystal synovitis caused by calcium pyrophosphatedihydrate (CPPD) as a diagnostic problem in orthopedic patients

ANDERS BJELLE & GORAN SUNDÉN

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Crystal synovitis (McCarty 1963) caused by microcrystals in joint cavities is now an established diagnosis with so far two crystallographically defined forms Sodium urate in gout and calcium pyrophosphate dihydrate (CPPD) in what is usually called chondrocalcinosis articularis or pseudogout (Mason 1966 McCarty 1966 Lagergren & Olhagen 1966 Munthe 1968) The clinical entity of chondrocalcinosis articularis based on X ray finding of calcification in articular and juxta articular structures and symptoms of arthritis was first described by Žitnan & Sitaj in 1958 (Žitnan & Sitaj 1963) Mc Carty & coworkers (1962) identified a non urate crystal CPPD in synovial fluids from patients with gout like symptoms and thus called the syndrome pseudogout These patients also had calcifications of the same type as described in the material of Žitnan & Sitaj Like urate (Seegmiller et al 1962) microcrystals of CPPD caused arthritis when injected in canine and human joint cavities (Faires & McCarty 1962) Later reports have suggested that the formation of pyrophosphate crystals is probably not one sole disease entity but a final stage common for abnormal methabolic path ways of several kinds (McCarty 1966) The authors suggest pyrophosphate synovitis as a simple and well defined diagnostic term for arthritis caused by CPPD microcrystals So far no other kind of pyrophosphate than CPPD in a crystal form has been shown to cause synovitis and thus calcium pyrophosphate dihydrate crystal synovitis (Webb et al 1970) could be shortened without risk of confusion The term chondrocalcinosis is restricted to any calcifi

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cation of cartilage as this can be of other origin than CPPD (McCarty 1966). Furthermore the finding of chondrocalcinosis does not mean that the patient had or will have joint symptoms (Phillips & Stark 1965).

Studies on the prevalence of calcifications in the knee joint (Zinn et al. 1969) in different countries have shown a variation between one to twelve per thousand in adult populations. In old people a prevalence of seven per cent has been found (Bocher et al. 1965, McCarty et al. 1966).

From Scandinavia some observations of clinical picture most likely being pyrophosphate synovitis have been reported (Edstrom & Norman 1951, Eklof 1952). Patients with the diagnosis of chondrocalcinosis have been reported from Denmark (Milde 1963, Ahlgren 1965), from Norway (Munthe 1967) and from Sweden (Lagergren & Olhagen 1967) where also several cases in one family have been observed (Bjelle & Berglund 1967).

In the orthopedic literature some reports have been published (Bundens et al. 1965, Mason 1966, Mann 1966, Hasenhuttle 1967) in recent years and the resemblance with acute suppurative arthritis has been pointed out (Hamblen et al. 1966).

In the Department of Orthopedic Surgery in Lund synovial fluids from most patients with synovitis in the knee joints and/or calcified menisci have been analysed for crystals by polarized light microscopy during the last half year and a surprisingly large number of patients (fifteen) with pyrophosphate synovitis was found.

The aim of the present communication is to draw attention to this disease. Pyrophosphate synovitis is apparently no rare cause of acute joint symptoms among cases attending clinics of orthopedic surgery.

Patients

The symptoms of the fifteen patients with pyrophosphate synovitis are given in Table 1. They were all attended at the Department of Orthopedic Surgery in Lund because of symptoms from the knee joints. Each patient had definite CPPD crystal deposition disease according to the diagnostic criteria of McCarty, i.e. in the synovial fluid from all patients crystals showing a weakly positive birefringence by compensated polarized light microscopy *and* the presence of typical calcifications in roentgenograms (see below) could be demonstrated.

The patients consisted of 10 men and 5 women, the mean age being

68 years (37–88) The average age when initial joint symptoms occurred was 60 years (range 37–87) for men 59 and for women 62 years One-third of the patients had had initial joint symptoms before the age of 50 years but none earlier than at 37 years No systematic difference in symptomatology between patients with initial symptoms before and after the age of 50 years could be observed in this material The duration of joint symptoms was on the average 8 years (0–25) one-third of the patients with symptoms for the first time Because of the severity of joint symptoms half of the patients had to be hospitalized most of them under the tentative diagnosis of septic arthritis Four patients were treated with antibiotics prior to definite diagnosis and two had received antibiotics at earlier attacks Only four of the patients had polyarticular symptoms two of those with symptoms from peripheral joints One patient (no 4) had a history of a distinct trauma to the right knee with subsequent symptoms and clinical findings of ruptured medial meniscus At operation this was confirmed but calcifications of the meniscus verified as CPPD in X ray diffraction and pyrophosphate crystals in the synovial fluid were also found

There was no indication in the laboratory values of rheumatoid arthritis hyperparathyroidism or diabetes mellitus among the patients The sedimentation rate was initially elevated in most cases and a week after the onset there was a tendency to even higher values in some cases over 100 mm/h After three to four weeks the sedimentation rate was usually normalized Serum uric acid was elevated in one patient with synovial fluid containing crystals of both urate and pyrophosphate

The most common type of symptomatology included acute attacks of arthritic symptoms with fever and elevated sedimentation rate the next common clinical picture was arthritic symptoms not affecting the general condition of health and without acute onset

With two exceptions no joint complaints among relatives were found

In the present material there seem to be certain discrepancies in symptomatology between the sexes In men there were mainly acute attacks of arthritic symptoms with heavy exudations Chronic joint symptoms were usually absent In women chronic joint symptoms similar to the symptoms of osteoarthritis predominated in some cases in combination with acute attacks of arthritis The mean age of the women was higher (nine years) on the average which might explain the higher incidence of chronic symptoms Almost all patients (thirteen) showed roentgenologic signs of osteoarthrosis in the knee joints

Table 1 Clinical data from fifteen patients wi

Pat no	a	b	c	d	e	f		g	h	i
						I	II			
1	88	♂	0	2	2 4 6	1	1	1	2	1
2	63	♂	0	20		1 2 3	1 2	1	2	2
3	61	♂	0	14		1	1	1	2	1
4	37	♂	0	0	8			4		4
5	59	♂	0	0	6 7	1 9	1	1	2	4
6	64	♂	0	10	1 4 5 7	1 5 6 8	1 4 5 6 8 9	3	2	3
7	79	♀	0	10	7	1	7	3	2	3
8	75	♂	0	0	1	1 3 9		1	1	4
9	71	♂	0	6	3	1	1 3	1	2	1
10	87	♂	0	0	1 4	1		2	2	4
11	74	♀	1	25	4 7	1 8	1 7 8	3	2	2
12	75	♀	0	20	7 9	1		3	2	3
13	47	♂	0	10		1 9	1	1	2	3
14	67	♀	1	0		1		1	1	4
15	76	♀	0	6	7	1	1 5 6	1	1	2

Coded data

a Age in years

b Sex ♂ = male ♀ = female

c Joint symptoms among relatives
- 0 neg finding
- 1 pos finding

d Duration in years of joint symptoms

e Accompanying disease
- 1 hypertension
- 2 gout
- 3 intestinal dis
- 4 heart dis
- 5 renal dis
- 6 renal dis with azotemia
- 7 degenerative joint dis
- 8 traumatic joint dis
- 9 skin dis

f Symptomatic joints (I/ now II/ earlier)
- 1 knees
- 2 hips
- 3 ankles
- 4 toes
- 5 shoulders
- 6 elbows
- 7 wrists
- 8 fingers
- 9 spine

g Characteristics of the actual symptoms
- 1 acute attack
- 2 subacute symptoms
- 3 chronic symptoms
- 4 no symptoms

yrophosphate synovitis (the key is given below)

k	l	m	n +	n −	o	p	r
4	2 3 4,5	3 4 5 6	7	4 5	1	1 3	1 3 6 7 8
2	2,3 4	2 5	6 7 8	5	1		4 5 6
4	1 2,3 4 5	3 4 5	7	2 4	1		6 7 8
		1 5	7		1		
2	1 2 3	1 5	1,2,3 4 7 8	5	1	2 4,5	
2	1 2,3	1 5	7		1	1 5	4
2	1,3 4 6	1 5	3 4 7	2	1	5	2
2	1,2,3 4	3 4 5	7		1		1,3 6 7 8
2	2 3 4,5	3 4 5	7				4
1	2,3 4	3 4 5	7	2 4	1	1 4	3 7
2	2 4 6	5	7	4	1	1 4	
2	2,3 4 6	1 5	7				
3	1 2 3 4	3 5	7	2,3 4	1	5	2 8
2	1 2,3 4	2 4 5	7		1		6
3	3 4	3 5	7		1		7

h Duration of present symptoms
- 1 less than one week
- 2 more than one week

i Characteristics of earlier joint symptoms
- 1 single attack
- 2 chronic symptoms
- 3 chronic symptoms with acute exacerbations
- 4 no symptoms

k. Degree of disablement in the acute stage
- 1 mobility unchanged
- 2 restricted walking
- 3 restricted to chair
- 4 restricted to bed

l Local findings
- 1 swelling
- 2 tenderness on palpation
- 3 painful movements
- 4 exudate
- 5 heat
- 6 decreased range of movements

m Synovial fluid
- 1 less than 2 ml
- 2 2–20 ml
- 3 more than 20 ml
- 4 cloudy
- 5 pyrophosphate crystals
- 6 urate crystals

n Roentgenographic examinations (with (+) and without (—) calcifications)
- 1 spine
- 2 shoulder
- 3 elbow
- 4 wrist
- 5 hip
- 6 symphysis
- 7 knee
- 8 ankle

o X ray changes other than calcifications
  1 osteoarthrosis

p Drug intake (for other reasons than joint disease) according to Pharmaconomia Suecia
  1 heart dis vessels dis (diuretics inclusive)
  2 intest dis
  3 antibiotics
  4 psych dis
  5 analgesics

r Treatment
  1 bedrest
  2 plaster cast
  3 emptying of exudate
  4 local steroids
  5 analgesics
  6 phenyl butazon
  7 indomethacin
  8 antibotics

To exemplify the most common clinical findings among our patients two cases are reported in more detail

Case 1 Farmer aged 63 During the last 20 years intermittently moderate pain in hips and knee joints Recently the patient had had a subacute attack of pain swelling and tenderness of the left knee with spontaneous regress of symptoms after a few days A week later there had been identical symptoms from the other knee joint and when admitted to hospital a few days later he also had pain on motion tenderness and swelling of the right hip and ankle points Temperature moderately elevated and an increased sedimentation rate (65 mm/h) Calcium phosphate alcaline phosphatases and uric acid in serum were all normal White blood cell count 11 000/mm² X ray films showed calcifications of the symphysis right knee and ankle joints apart from extra articular calcifications around the right hip cartilage calcifications in the right ankle joints In synovial fluid from the right knee joint few but typical CPPD crystals were found mainly in the leucocytes

Case 2 A woman of 75 who had had myocardial infarction in 1964 For 25 years the patient had had bilateral knee joint symptoms which were diagnosed as osteoarthritis She had repeatedly been treated with physiotherapy and local injections of corticosteroids The last few years the patient also had intermittent pains and stiffness of the cervical and lumbar spine During 1969 her pains of the right knee joint gradually increased Sudden worsening of the symptoms with heavy exudation fever and increased sedimentation rate caused hospitalization under the diagnosis of septic arthritis and treatment with antibiotics Repeated cultures from synovial fluid were negative however and the symptoms rapidly subsided

About one year later she had a new attack with pains in both knee joints moderate exudation no fever but an elevated sedimentation rate of 45 mm/h Roentgenologic examination of the knee joints revealed pronounced osteoarthrosis but also calcifications of the menisci Subsequent microscopic examination of synovial fluid revealed CPPD crystals

DISCUSSION

The number of patients in the present material are too few to allow detailed analysis Thus the aim of this presentation is mainly to draw attention to the diagnosis of pyrophosphate synovitis in order to obtain more information of its clinical picture

In the material of McCarty (1966) which is the most well known about three-quarters of the cases appeared as chronic progressive osteoarthrosis usually with intermittent attacks of acute arthritis About one fourth had attacks with symptom free intervals Exceptional cases had peripheral joint involvement clinically similar to rheumatoid arthritis Epidemiological studies have shown (Zinn et al 1969) that the clinical picture varies between different countries which might explain the difference between the present material and that of McCarty A selection of cases (most of our patients have consulted the Department of Orthopedic Surgery as acute out patients) might be another explanation to this difference

Žitnan & Sitaj (1963) originally named the new syndrome "chondrocalcinosis articularis familiaris as most of their cases were found in a few families In the present material no case of hereditary chondrocalcinosis could be confirmed with certainty

McCarty (1966) suggested the following diagnostic criteria in analogy with rheumatoid arthritis *Possible* diagnosis based on the clinical picture only with either acute aseptic arthritis in the large joints or chronic arthritis accompanied by acute exacerbations The diagnosis is considered *probable* if crystals can be identified in polarized light microscopy (Figure 1) *or* typical calcifications are seen in the roentgenograms Typical X ray findings are punctuate or linear calcifications of menisci and in articular cartilage where they are seen as a double contour of the bone (Figure 2a-c) The diagnosis is considered *definite* when crystals in synovial fluid *and* calcifications in X ray films could be demonstrated *or* the CPPD crystals identified by X ray diffraction (Figure 3) This gives the fingerprints of the crystals but when they *are scarce in the synovial fluids biopsy is required (Bjelle & Sundstrom* 1969) Thus pyrophosphate synovitis can simulate almost any acute or chronic joint disease Furthermore it might co-exist with another joint disease e g gout and rheumatoid arthritis in the former both types of crystals can be found (Moskowitz & Katz 1965) as they were in one of the cases Osteoarthritis is also a common finding but whether primary or secondary is still a matter of discussion (Curry et al 1966)



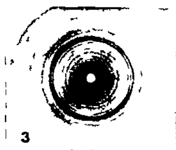
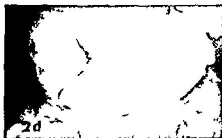


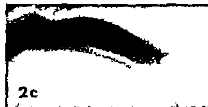
Figure 1 Typical crystals of calcium pyrophosphate dihydrate (CPPD) showing weakly positive birefringense

Figure 3 X ray diffraction pattern of calcium pyrophosphate dihydrate crystals from a semilunar cartilage









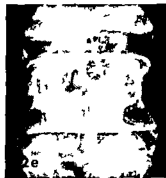


Figure 2 Details of X ray films showing typical cartilage calcifications in the (a) knee (b) pelvis (c) shouder (d) wrist and (e) lumbar spine In Figure 2 b typical periarticular calcifications can also be seen

It has been questioned whether a few CPPD crystals in the synovial fluid of patients with calcified menisci really cause the symptoms in many of those instances (Moskowitz & Katz 1965) Symptoms from the spine and calcified intervertebral disc have been noticed with varying frequency (Sitaj & Žitnan 1969) In the present study however notably few patients presented symptoms from the neck and back

There seems to be an increased frequency of metabolic disturbances in these patients e g hyperparathyroidism (Wang et al 1969) diabetes mellitus (Solnica et al 1966) and hyperuricemia as well as azotemia (Moskowitz & Katz 1967) and haemochromatosis (de Sèze et al 1964) In the latter deposition of apatite and not CPPD in the menisci has also been observed (Bauer & Jeffries 1965) The following tests are of value in patients with arthritis and calcified menisci and/or pyrophosphate crystals uric acid in blood or serum calcium phosphate and alcaline phosphatases in blood or serum rheumatoid factor tests and test for glucosuria X ray examination of joints giving symptoms most often reveals typical calcifications which are usually most easily recognized on examination of knees pelvis (hips and symphysis) and wrists Acute attacks usually subside spontaneously in one or two weeks without treatment but the intensity of the pain often motivates therapy

So far only symptomatic treatment is at hand and is at large the same as in acute gout i e fenylbutazon and indomethacin Fenylbutazon may cause water retention especially in elderly which was experienced in one of our patients Removal of crystals by aspiration of joint fluid with subsequent local injection of corticosteroids and conservative treatment with bed rest and abolished weight bearing often give relief of symptoms in the acute stage

It is important to identify the disease to avoid unnecessary antibiotic therapy in cases simulating septic arthritis to avoid cloroquine gold or systemic corticosteroid therapy in patients with a clinical picture suggesting rheumatoid arithritis etc Furthermore the joint symptoms might be the first sign of a hyperparathyroidism or one of the other systemic diseases mentioned above although so far no proof that adequate therapy of these diseases halts the process of pyrophosphate deposition or synovitis has been demonstrated

SUMMARY

The denomination pyrophosphate synovitis of the arthritis symptoms caused by calciumpyrophosphate dihydrate (CPPD) is suggested for replacing the formerly used terms chondrocalcinosis and pseudogout

During half a year fifteen new cases of pyrophosphate synovitis have been diagnosed among patients attended at the Department of Orthopedic Surgery in Lund This surprisingly great number makes the diagnosis important to orthopedic surgeons for the symptoms closely resemble other kinds of joint disease especially septic arthritis

The aim of this communication is to draw attention to pyrophosphate synovitis by giving a summary of our own cases and a short review of the recent literature

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Departments of Pediatrics and Orthopedics University Hospital
Uppsala Sweden

BCG OSTEOMYELITIS AND OSTEOARTHRITIS AS A COMPLICATION FOLLOWING BCG VACCINATION

Tony Foucard & Åke Hjelmstedt

Accepted 24 ii 71

Severe complications following BCG vaccination are rare with regard to the great number of vaccinations performed in many countries BCG infections leading to death have been reported in 13 cases (Mande 1968) Six of these cases are reported from Scandinavia (Hollstrom & Hard 1953 Meyer & Jensen 1954 Thrap Meyer 1954 Fall mer Lind & Ploman 1955 Gardborg et al 1963 Carlgren et al 1965) Clinical data indicate however that most of these cases had defective immunity of congenital or acquired type (Matsaniotis & Economou Mavrou 1966) In some cases there was also a hypogammaglobulinemia

Of other complications following BCG vaccination osteomyelitis and osteoarthritis are of special interest These complications are probably more common than the lethal BCG infections and seem to occur in persons with apparently normal immunity We have found 13 reported cases with BCG etiology verified by culture Of these 9 are from Scandinavia and 1 from each of the following countries Germany Austria France and Algeria (Mimouni 1951 Falkenfleth 1954 Mork bak 1954 Imerslund & Jensen 1955 Bang Ingbriel & Nielsen 1960 Haraldsson 1960 Virtanen & Lindgren 1962 Lellander 1963 Simos et al 1965 Wallerstrom & Lnell 1966 Dahl & Halvorsen 1967 Sacrez et al 1967) Similar clinical pictures in BCG vaccinated children have been reported by several authors (Passeau Sorrel & Nguyen Khac Vien 1941 Backman & Wallgren 1954 Fellander 1963) but in these cases cultures had not been performed or had been negative

Despite the few reported cases of BCG osteomyelitis or osteoarthritis it is possible for any pediatrician and orthopedic surgeon to encounter such cases Since these cases often give diagnostic difficulties we have found it of interest to compile the experiences of

cases reported in the literature and of one case of our own with verified BCG etiology Moreover we have tabulated the results of a questionnaire to all pediatric and orthopedic clinics in Sweden concerning possible cases of BCG osteomyelitis or -arthritis during the last two decades

MATERIAL

This includes one case of osteomyelitis caused by BCG verified by culture (case 1) and another 4 cases of osteomyelitis or osteoarthritis (cases 2–5) suspected to be complications of a BCG vaccination performed in the neonatal period but in these cases cultures have been negative All these cases were encountered during a 3 year period

1 Girl (B M A) born on January 9 1967 BCG vaccinated intracutaneously in the neonatal period without abnormal reaction at the injection site At 15 months of age she sustained slight trauma to her right knee Afterwards she was reluctant to stand on the leg and the knee was somewhat swollen The X ra s were normal 2 weeks after the trauma but 10 days later an osteomyelitic process was noted with a central breakthrough in the epiphyseal plate There were intermittent periods of low grade fever No reaction could be seen at the vaccination site Normal amounts of granulocytes lymphocytes and immunoglobulins were recorded Micro sedimentation rate (MSR) 40 mm/hr Tuberculin positive with Moro test negative with Mantoux 1/10000 OT Normal chest X ray She was treated with large doses of penicillin ampicillin cephalosporin and sulfa In spite of this treatment there was a progressive destruction which prompted surgical exploration The abscess had perforated the cortex and had also spread to the adjacent soft tissues Culture was negative on material from the marrow cavity but on material from the periphery of the subcutaneous abscess, growth of acid fast bacilli was obtained on Loewenstein s medium Closer examination of this culture at the BCG laboratory in C thenburg showed this material to be indistinguishable from a BCG-culture Guinea pig inoculation caused no reaction She was treated with INH and PAS for one year In spite of the br akthrough in the epiphyseal plate the skeletal growth seems to have been grossly n rmal with a slight tendency to accelerated growth of the femur

2 (T J 661128) A one year old boy with o teoarthritis in his left hip and a radiological progress in spite f intensive antibiotic therapy He ha l a low grade fever along with a MSR of 25 mm/hr Normal immunoelectrophoresis, normal amounts of lymphocytes Mantoux positive 1/1000 At operation 2 months after the onset of the illness greyish villous growths were curetted. The histological picture vas compatible with tuberculosis

3 (A F C5069C) A twenty month old b de el ped pains swelling and heat in his left knee No fe er MSR -0 mm Neotuberculin test positive X rays of his knee repeate l 2 week later showed no skeletal abnormality The presumptive diagnosis was rheumatoid arthriti and he was treated with acetylsalicylic acid and periodi cally also ster id with apparent improvement A new X ra half a year later

revealed a destruction in the femur metaphysis with a breakthrough to the epiphysis At exploration small amounts of sterile pus were found Histologic examination showed the picture of a chronic granulomatous process

4 (J L 670724) An eighteen month old girl who after a slight trauma to the sternum became locally tender and developed an increasing swelling measuring 3 × 3 cm after 10 days An X ray showed destruction of the lower corpus sterni MSR 26–34 mm other laboratory data were normal Radiological examinations of the lungs skull extremities and kidneys were normal The corpus sterni and surrounding soft tissues were extirpated because of suspected malignancy No culture specimens were taken Histologic examination showed the picture of tuberculosis

5 (E L E 680903) A fifteen month old girl with increasing pains and swelling in her right ankle after a slight trauma Two weeks later X rays showed a destruction of the distal fibular diaphysis but other bones and the lungs were normal Histologic examination of excised material showed tuberculosis No anemia. MSR 15 mm Normal amounts of immunoglobulins and lymphocytes in the blood Tuberculin test positive with Mantoux 2 TU PPD Normal sensitization with dinitrochlorobenzene

Questionnaire study Because these 5 cases happened during a 3 year period the question arose whether an increase in this type of complication following BCG-vaccination had occurred or not To study the frequency of these complications a questionnaire concerning verified or suspected cases of BCG tuberculosis during the period 1950–1970 was sent to all pediatric and orthopedic clinics in Sweden at the beginning of 1970 Ninety percent of the clinics answered with records or record excerpts concerning 28 children None of these cases had been verified by a positive culture Therefore it was only a matter of estimation as to whether a possible BCG infection had occurred or not It was held probable that a BCG infection had occurred when the following criteria were fullfilled

1 A BCG vaccination had been performed
2 Less than 4 years had passed between the vaccination and the moment the child became ill
3 A known tuberculous contact was lacking
4 The clinical picture was in agreement with that reported in the literature in cases with BCG osteomyelitis or osteoarthritis
5 In explored cases the histological picture indicated tuberculosis

Eight of the cases reported in the questionnaire fullfilled the above criteria One more child was suspected of having had a BCG osteomyelitis but in her case the time interval between vaccination and

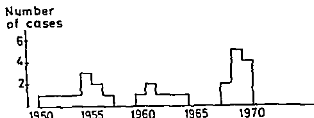


Figure 1 *Reported cases of BCG-osteomyelitis or osteoarthritis from Swedish Departments of Pediatrics and Orthopedics (1950–1970)*

apparent disease was 56 months In spite of that she was included in the series In addition to these cases Fellander (1963) Haraldsson (1960) and Wallerstrom-Enell (1966) have reported one case each of BCG osteomyelitis verified by growth of BCG Besides Felländer reported 9 similar cases where culture had not been taken or had been negative One more case fullfilling the above mentioned criteria has been treated in 1961 by one of the authors

In Sweden during the period 1950–1970 we now have knowledge of 23 cases of probable BCG osteomyelitis and 4 cases of BCG-osteomyelitis verified by culture If the suspected cases really were caused by BCG the frequency of this type of complication would be about 1 80 000 in BCG vaccinated children in Sweden This figure has been calculated from the estimation that more than 90 per cent of all children born in Sweden between 1950 and 1970 (about 2 1/4 million) have been BCG vaccinated The distribution in time of the 27 known cases will be seen in Figure 1 It shows a slight increase of the number of cases during the last 3 years but no definite conclusions may be drawn from the relatively small series

Clinical, roentgenological histological and bacteriological findings and treatment results of BCG osteomyelitis in bones and joints

The following summary is based on the literature data from 13 reported cases of BCG osteomyelitis or osteoarthritis and of our own case verified by culture

Sex distribution Seven boys six girls In one case the sex was not mentioned

Onset of symptoms The first symptoms have as a rule been noticed about 12 months after the BCG vaccination (range 3–26 months)

Clinical symptoms Usually local swelling erythema and tenderness When the process was near a joint there was often a limitation of the

joint movements caused by pain and accompanied by limping when the process was localized to the lower extremities. The general condition was usually normal or only slightly changed. Six patients were said to be afebrile, five had low grade fever and for the remaining three information was lacking.

Table 1. Localization of foci in children with BCG osteomyelitis or osteoarthritis verified by culture

Localization of foci	Number of patients	Number of foci
Long bones		
(epiphyses and metaphyses)	12	13
Ribs	1	6
Vertebrae	2	4
Talus metatarsus	3	3
Clavicles	1	2
Ilium	1	1
Total	14	29

Localization. In three of the cases there were multiple foci accounting for a total of 29 foci in 14 patients (Table 1). Twelve of the children had destruction in the metaphyses and/or epiphyses of the long bones. The remaining two children had changes in the talus and the first metatarsal respectively. Foci in vertebrae, ribs, clavicles or the ilium were only found in children who also had a focus in one of the long bones.

Radiological findings. The BCG osteomyelitis was seen as a localized osteolytic process that could be demarcated and could give the appearance of a cavity. Sometimes a breakthrough in the cortex was noted. In 3 cases there was a cavity both in the distal metaphysis and the epiphyses of the femur with a connecting fistula in the middle of the epiphyseal plate. Reaction in the periosteum in the form of "spina ventosa" was found in one metatarsal bone and in other cases thick stratified periosteal thickening was noted in the metaphyses of the long bones.

Laboratory data. The MSR varied from normal up to 40 mm/hr. No anemia. The total white counts ranged from 4 800 to 16 800/mm³ with a normal proportion of lymphocytes. Immunoelectrophoresis was performed in 6 cases; no abnormalities were detected.

The Mantoux reaction In 9 cases the Mantoux reaction was positive In another case the reaction was said to be of phlyctenular type In one case the reaction was negative In remaining cases information was lacking

Pathological anatomical findings At operation granulation tissue and small amounts of pus were found Microscopically epithelioid cell granuloma with central caseous necrosis and giant cells of Langhan s type were seen In the periphery there were numerous plasma cells and a smaller amount of lymphocytes

Bacteriological findings Acid fast bacilli were found in a smear in one case (Virtanen Lindgren) and in a histological preparation in another case (Fellander) Culture on Loewenstein s or Loewenstein Jensen s medium was positive at 37 C in all 14 cases but was negative at 20–22 and 44–45 where such tests had been performed (Bang et al Eng & Aaneland Fellander Virtanen & Lindgren) At the inoculation on guinea pigs no or only local infiltration and sometimes regional lymphadenitis with caseous necrosis has been observed (Eng & Aaneland Imerslund & Jensen Virtanen & Lindgren) but no general dissemination

Treatment and course Anamnestic data are very scarce in many cases but in those cases where information has been given at least 2 months seemed to have elapsed between the onset of symptoms and the diagnosis The treatment consisted of local excision or curettage immobilization INH PAS and in a few cases also streptomycin A primary healing was achieved in most cases but in some cases a fistula developed The regression after onset of treatment has been rather rapid Radiologically the course has ranged from total healing after 6 months to remaining but decreasing skeletal changes after 16 months In 2 cases a growth disturbance has been reported with a 2 cm shortening of the femur (Virtanen Lindgren) and a slight shortening of the ulna (Morkbak) In our own case a slight lengthening of the femur was noted In the case reported by Haraldsson there was a slight flattening of the trochlea tali

DISCUSSION

Frequency The calculated frequency (1 80 000) for BCG-osteomyelitis or arthritis is probably too low Incomplete registration and reporting diagnostic difficulties in tuberculous cases and possible spontaneous healing before the diagnosis has been settled might contribute to a

falsely low frequency Even considering this the risk of skeletal complications following BCG vaccination must be regarded as very low

Diagnostic points of view It is important to establish an early diagnosis of BCG osteomyelitis or arthritis because of the risks of destruction of joints and epiphyseal plates The diagnosis however is difficult to make which fact is underlined by the period of time at least 2 months that usually elapses between onset of symptoms and the tentative diagnosis The clinical symptoms are uncharacteristic and usually less pronounced and the blood picture and sedimentation rate show fewer changes compared with other cases of bacterial osteomyelitis in children BCG etiology ought to be suspected when the following criteria are fullfilled

1 The infection seems to be of low virulence
2 When no regression is seen after some weeks treatment with antibiotics effective against gram positive cocci
3 When less than 4 years have elapsed since the BCG vaccination

These criteria concern children only It is uncertain whether these skeletal complications may also occur in BCG vaccinated adults When a BCG osteomyelitis or -arthritis is suspected the whole skeleton ought to be X rayed in order to reveal other possible foci A correct diagnosis can only be obtained with a biopsy and specimens taken for bacteriological and histological examination The bacteriological specimens ought to be taken both from the pus and the granulation tissue In most cases there is no growth of acid fast bacilli in spite of a histological picture clearly indicating tuberculosis This may probably depend on the low virulence of the BCG In our tabulation such cases with no growth of BCG were 4 times as common as the cases with growth of BCG (16 of 20 cases) The BCG etiology may in these cases be suspected but not established

If culture on Loewenstein s medium shows growth of acid fast bacilli while the guinea pig test is negative or only shows local lymphadenitis there is strong evidence of BCG infection To verify the BCG etiology the suspected colony has to be compared with a BCG colony regarding possible growth when cultured on different media and regarding reaction in sensitivity inoculation and cytochemical tests

Treatment Local excision and/or curettage is a pre-requisite for a correct diagnosis A complete curettage is desirable along with irrigation and drainage Immobilization is recommended until clinical heal

ing is achieved Antituberculous chemotherapy should be given and as a rule the combination of INH and PAS is enough Streptomycin may be used exceptionally

Prognosis The reported cases have healed rather quickly with treatment The degree of lasting disability after BCG-arthritis depends on the degree of joint destruction A growth retardation has been reported in some cases (Morkbak Virtanen-Lindgren Haraldsson) but the disabilities seem to have been of a minor degree

Etiological points of view After the BCG vaccination a dissemination of BCG occurs in the body from the injection site Within 6 weeks proliferative epithelioid cell groups may be seen in different parenchymatous organs This dissemination seems to occur whether the vaccine is deposited intracutaneously or subcutaneously There is a further development of the proliferative changes during the first months but then they slowly regress (Stojanov & Zagurov 1963) Even 40 months later granuloma rests may be seen in the viscera in some cases (Gormsen 1956) It seems reasonable to suspect these foci to be the origin of the reported skeletal changes Why there is a progress in these patients is unclear Examination of isolated BCG cultures in BCG-osteomyelitis has given no evidence of increased virulence (Bang et al Wallerstrom-Enell Virtanen-Lindgren) Therefore it is probably the resistance of the vaccinated child that is reduced Defective humoral immunity with lack of immunoglobulins does not seem to create any obstacle in contrast to defective cellular immunity in the development of normal resistance to BCG and human tubercle bacilli (Matsaniotis & Economou-Mavrou Parkes 1958) However no humoral or cellular immunity defects have been shown with certainty in the described cases This may depend on the fact that no defective immunity had ever existed that our methods for evaluating such defects are too insensitive or that a defect had existed at the onset of the illness with a normalization at the time of the examination

Temporarily reduced cellular immunity manifested by inhibited tuberculin reaction may be seen in sarcoidosis and such virus diseases as morbilli varicella rubeola and influenza It is possible that certain virus infections may interfere with the response of the host to BCG and this could promote an increased activity in already existing BCG foci Imerslund & Jensen have described a local lupus reaction over the BCG vaccination site in connection with measles 10 months after the BCG vaccination Moreover in one of our own cases of suspected BCG osteitis observed earlier by one of the authors the

onset of the osteomyelitic symptoms was noted a short time after a smallpox vaccination and a local trauma

It is very difficult to evaluate the importance of a preceeding trauma as a cause of BCG osteomyelitis but Rich (1951) finds it probable that *such a connection exists In our questionnaire a preceeding trauma* was reported in 13 of the 27 cases

SUMMARY

1 The authors give an account of one verified case of BCG osteomyelitis and four other cases with suspected BCG etiology More over a tabulation of 13 literature reported cases of BCG osteomyelitis and osteoarthritis verified by culture is made
2 The diagnostic difficulties are underlined BCG-etiology ought to be suspected when the infection seems to be of low virulence when antibiotic treatment gives no signs of regression after some weeks and when less than 4 years have elapsed since the child has been BCG vaccinated
3 Bacteriological culture is positive only in about 1 of 5 cases
4 The prognosis is good but there is a risk of joint deformity and growth disturbances in the affected bone
5 The frequency of verified and suspected cases of BCG osteomyelitis and/or -osteoarthritis in Sweden is estimated to be at least 1 80 000 in BCG vaccinated children
6 The question of a possible predisposing maybe temporary immunological defect is discussed

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Orthopedic Surgical Department and Neuroradiological Department
University Hospital Copenhagen Denmark

ANGIOGRAPHY IN TUMORS OF THE EXTREMITIES

J LESTER A ROSENKLINT TH ROVSING N STEPHENSEN &
F STRUVE CHRISTENSEN

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Angiography in tumors of the extremities has been employed since 1929 when Dos Santos & J Caldas reported their primary experiences In 1950 these same authors described the angiographic characteristics of various disorders of the extremities These were later confirmed and extended by other authors especially Strickland (1959) On the basis of the current literature it is possible to establish certain criteria upon which in the majority of cases it is possible to differentiate between malignant and benign processes The signs of malignancy comprise

1 *Pathological arteries*, i e newly formed randomly distributed cylindrical or uneven vessels sometimes of varying diameter These often display a more or less ordered pattern resembling a net paint or toothbrush Some arteries end abruptly others lead into lacunae (Figure 1)

2 *Pooling* i e irregular larger or smaller concentrations of contrast medium resembling pronounced vascular dilatations or non endothelial covered interstitial pools of blood in necrotic tumor tissue (Figure 1)

3 *Shunts* which are defined as very rapid filling of veins because of almost direct arterio venous connections (Figure 2)

4 *Veins* extending transversally over the surface of the tumor (Figure 2)

Phenomena such as hyperemia simple vascular dislocation and accumulation of contrast medium (flushing) may be seen in both benign and malignant tumors (Strickland 1959 Lindbom et al 1960) Hypervascularization with pooling and shunt may be seen in benign

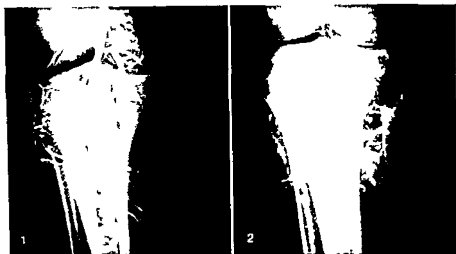


Figure 1 Osteosarcoma in an early phase of angiography with numerous pathological arteries some of which end abruptly and with characteristic pooling
Figure 2 Osteosarcoma in a late phase of angiography demonstrating rapid venous filling (shunt) and large veins extending transversally over the surface of the tumor

processes such as hemangioma (Cockshott & Evans 1964 Rösch 1964) inflammation (Cockshott & Evans 1964 Lagergren et al 1958) and organized hematoma (Stener & Wickbom 1966) With a single exception (Cockshott & Evans 1964) pathological newly formed vessels have only been described with malignant tumors Lagergren et al (1960 1961 a b 1962) in particular have shown a high correlation between the degree of vascularization and malignancy These authors and others (Diethelm et al 1969 Mucchi et al 1960 Rösch 1964) emphasize that more precise identification is not possible with angiography

Most authors regard angiography as a valuable supplement to other methods of investigation It allows differential diagnosis between malignant and benign tumors it provides a relatively precise indication of the size of the tumor it suggests the optimal site for biopsy and finally it provides guidance in operative intervention (Rosenberg 1964)

The aim of the present work has been to assess the accuracy of differential diagnosis and to evaluate the practical value of angiography in tumors of the extremities

MATERIAL AND METHODS

The material comprised 84 patients with tumors of the extremities referred to the Department of Orthopedic Surgery University Hospital Copenhagen Patients were selected on the basis of whether in the preceding five year period a reasonably successful angiography had been obtained (Three patients were excluded from the study because of inadequate angiographs three others because their angiograms were missing at the second follow up) All cases had been histologically verified often by several pathologists as is customary with bone tumors which as is well known often present major difficulties in diagnosis even for pathologists Angiography was carried out seriographically in the conventional manner in two planes with the contrast medium injected as close to the tumor as possible The angiograms were assessed twice the second time by two of the present authors who made an independent examination of all pictures without knowledge of the original roentgenological description or of the histological diagnosis The angiographs were graded only as to whether the pathological changes were benign or malignant The assessments of the angiograms were ultimately compared with the original roentgenological descriptions in the case histories

RESULTS

The material was distributed according to age and sex as shown in Table 1 The youngest patient was 8 years old the oldest 72 years of age

Table 1 Age (in years) and sex of the investigated material

	0–20	20–40	40–60	Over 60	Total
Women	5	7	11	13	36
Men	18	8	13	9	48

Table 2 Angiographic diagnosis of malignant osseous processes

	No	Malignant	Benign	Normal
Osteosarcoma	17	17		
Parosteal osteosarcoma	1		1	
Ewing s sarcoma	3	2	1	
Chondrosarcoma	5			
Malignant osteoclastoma	2	2		
Fibrosarcoma	1	1		
Reticulosarcoma	1	1		
Metastases	4	4		
Total	34	32	2	0

The material was classified according to benign or malignant processes in the bones and soft tissues respectively as may be seen in Tables 2–5

Table 2 shows that all osteosarcomas were correctly diagnosed whereas a parosteal sarcoma was erroneously judged to be benign (a false negative)

This was a 5 × 12 cm solid osseous avascular tumor which had previously been treated radiologically

One of the 3 Ewing s sarcomas was erroneously assessed as benign

This was a 3 × 4 cm solid, immobile tumor at the site at which 5 years previously a tumor had been extirpated and radiologically treated

All other malignant bone tumors were correctly identified

Table 3 Angiographic diagnosis of benign osseous processes

	No	Malignant	Benign	Normal
Simple cyst	2		2	
Aneurysmal cyst	2		2	
Osteoclastoma	1		1	
Osteitis	4		4	
Periosteitis	1			1
Incomplete fracture	2		2	
Total	12	0	11	1

Table 3 shows that none of the benign bone processes was erroneously judged to be malignant

Table 4 indicates that two of the fibrosarcomas the most frequent tumor of the group were incorrectly assessed

One which was judged to be benign was a 17 × 22 cm tumor at the site of a former tumor in the femural adductor muscles An extirpation had been performed 3 years previously followed by radiological treatment

The other case involved a 25 × 5 × 5 cm sharply defined tumor lying subcutaneously in the trigonum scarpae On 3 previous occasions a tumor had been extirpated at this site.

One of the four rhabdomyosarcomas was judged to be benign

This was a 3 × 9 × 10 cm tumor situated proximally in the left femural adductor muscles close to the vessels There had been no previous operation or

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Malignant osteoclastoma	2	2		
Fibrosarcoma	1	1		
Reticulosarcoma	1	1		
Metastases	4	4		
Total	34	32	2	0

correctly described and 4 erroneously graded at the second control In two cases of fibrosarcoma the first assessment was correct but the second was erroneous

DISCUSSION

Like other authors we have found a good correlation between angiographic and histologic diagnoses of malignancy Angiographic assessment was most accurate for the often highly vascularized osteosarcomas Hipp (1968) and Scholz (1953) believe that angiography renders pre-operative biopsy unnecessary At present we do not fully agree However this study and other investigations (Leroux & Delvigne 1967 Strickland 1959) support such an idea when the angiograms are definitely positive Only a single false negative angiographic finding has been reported for osteosarcoma (Koskinen et al 1968) Lagergren et al (1961 a) state that sclerotic tumors are poorly vascularized and are thus difficult to assess This is supported by our false negative diagnosis in a case of parosteal osteosarcoma

The diagnosis of Ewing s sarcoma is difficult whether by pathology or by angiography Poppe (1969) has demonstrated that 20 of 59 Ewing s sarcomas could not be distinguished from osteomyelitis Lagergren & Lindbom (1962) concur in this statement Hipp (1968) and Dos Santos (1950) are of the opposite opinion and assert that Ewing s sarcomas always present pathological vessels within the tumor whereas osteomyelitis does not Mucchi et al (1966) are of the same opinion they believe that tumor vessels always occur in Ewing s sarcoma and state that pathological arteries resembling a crumpled metal wire are especially characteristic (Figure 3) Our material is too small to contribute to this discussion although we have noted "crumpled metal wires in osteitis and eosinophilic granuloma

Osteoclastomas may often present difficulties in angiographic diagnosis as the more active forms may resemble malignant tumors (Strickland 1959 Mucchi et al 1966) In our material erroneous grading of this type of tumor occurred only at the first inspection

Fibrosarcomas fall into two groups those which are richly and those which are poorly vascularized (Lagergren et al 1960) The latter may lead to a false negative diagnosis as happened in two of our cases

Rhabdomyosarcomas are often highly vascularized (Lagergren & Lindbom 1962) and were therefore generally correctly identified on angiographs in our material as was the case in the investigation by



Figure 3 An almost avascular Ewing's sarcoma with some arteries resembling crumpled metal wire

Rosenberg (1964) Our material offered a single exception to this however in that one rhabdomyosarcoma was definitely avascular and was thus misinterpreted This tumor had not previously been subjected to either operation or radiologic treatment

Reticulosarcomas are most often graded correctly (Diethelm et al 1969) In our material there was a single false negative diagnosis in this group Strickland (1959) also found a single false negative assessment in his investigation but in his case radiologic treatment had preceded angiography

Thus we found a total of 6 false negative diagnoses of which 3 tumors had previously received radiologic treatment Radiologic treatment is as has been shown by Strickland (1959) and Breit (1969) of major influence for angiography in that the blood vessels in and near the tumor are altered and become unrecognizable especially if the tumor is radiosensitive Two of the radiologically treated cases were also surgically treated One tumor was a regrowth on the site from which tumors had been extirpated several times previously In 2 cases there were regularly false negative assessments of tumors which are normally highly vascularized It should, however be noted that neither of the angiograms was technically satisfactory

There were no false positive findings Diethelm et al (1969) have reported one case in which a histologically benign chondromyxoid fibroma appeared to be malignant by angiography Staple et al (1968) have reported on one case in which ordinary X ray photographs and biopsy indicated an aneurysmal bone cyst whereas angiography suggested malignancy and a subsequent new biopsy taken on the basis of the angiographic findings demonstrated malignancy False positives are thus rare and should when they appear be taken as an indication of the need for re biopsy guided by the angiographic picture

It is thus our experience like that of other authors that only genuinely pathologically formed arteries may be taken as a definite indication of malignancy We have found transversal veins which are regarded as almost pathognomic by Strickland (1959) in an aneurysmal bone cyst and Staple et al (1968) also describe extensive formation of veins in this type of tumor as well as in giant cell tumor and osteitis fibrosa

CONCLUSIONS

We like many other authors conclude that angiography of bone and soft tissue tumors is according to the above criteria and when assessed by experienced radiologists a reliable guide when it demonstrates malignancy whereas indications of benignity on an angiogram do not exclude the possibility of a malignant tumor As a rule angiography gives an excellent picture of the extent of the tumor which is often larger than might be expected from clinical investigations and ordinary roentgenograms Angiography may thus be used as an operative guide in making biopsies for the excision of soft tissue tumors and in the preparation for necessary surgical intervention

Angiography is a valuable supplement to other methods of investigation In the case of the highly vascularized rapidly growing highly malignant sarcoma convincing findings of malignancy on the angiograph may promote earlier operative intervention by eliminating the necessity of pre-operative biopsy

SUMMARY

After a short survey of the literature to establish the angiographic criteria of malignancy (pathological arteries pooling shunt extended veins) a material of 84 patients is presented All patients were angiographed and all diagnoses were histologically verified Good agreement

was found between the histologic and the angiographic diagnosis in deciding between malignancy and benignancy The diagnoses of osteosarcomas showed the greatest accuracy In six cases angiography gave false negative findings in one case after previous radiologic treatment in two cases after combined surgical extirpation and radiologic treatment and in one case after repeated extirpations whereas in two cases the false negative findings could only be explained by technically inadequate angiograms It is concluded that a positive angiogram is reliable for the diagnosis of malignancy but less reliable if the angiogram indicates a benign tumor or no changes In addition angiography has in many cases offered excellent guidance for operative intervention

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Department of Orthopaedics and Traumatology,
University Central Hospital, Helsinki

AO OSTEOSYNTHESIS OF FRACTURES OF THE DISTAL THIRD OF THE FEMUR

P. Slätis, S. Ryöppy & V.-M. Huittinen

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Fractures of the distal third of the femur comprise about 10–15 per cent of all fractures of the femoral shaft. They may be classified according to the site of the lesion as metaphyseal, supracondylar and condylar fractures, or as conjoined fractures of both the metaphyseal and condylar regions (Stewart et al. 1966). Common treatment problems comprise restoration of the distal articular joint surface, adequate fracture retention and avoidance of subsequent stiffness of the knee joint due to fibrosis in the suprapatellar region.

The good osteogenic properties in the cancellous bone and the ample blood supply in the distal third of the femur usually allow rapid consolidation of the bone fragments. In fractures of slight to moderate severity *union is usually achieved in 5 to 8 weeks (Charnley 1963, Neer* et al. 1967). Hence most authors recommend non-operative treatment in these cases (Watson-Jones 1955, Fisk 1962, Charnley 1963, Neer et al. 1967).

There remain, however, the severe fractures of the distal third of the femur. These are usually sustained in traffic accidents by axial impact against unyielding structures, either in car accidents by dashboard injuries (Buttner & Friedhoff 1959, Ritchey & Schonholtz 1958) or in *motorcycle accidents by a severe blow against the flexed knee* (Vollmar & Benz 1960). These fractures are frequently compound and often extend *into the knee joint. Several operative procedures have been* advocated: medullary pins (Rush & Gelbke 1957), blade plate fixation (Altenberg & Shorkey 1949), plates and screws, and combinations of these. The results have been discouraging, owing both to inadequacies of the metallic implants and to inexact indications for surgical intervention. Thus Neer & coworkers (1967), in a review of 110 supracondylar fractures, state that no category of fractures is well suited

for internal fixation and that satisfactory results can only be obtained in 52 per cent of operated cases

Recent development of straight and angled heavy AOI compression plates by Müller et al (1965) has provided better facilities for stable internal fixation of these fractures (Anderson 1965) Both Neff (1966) and Olerud (1966) reporting small series treated by this method claim encouraging primary results The superiority of the compression method is still unconfirmed however (Wade 1970) and further reports therefore seem justified

MATERIAL AND METHODS

The series comprises 21 fractures of the lower third of the femur in 20 patients treated by the AOI technique at the Department of Orthopaedics and Traumatology University Central Hospital Helsinki during the years 1966–1968

There were 12 male and 8 female patients their ages ranging from 17 to 70 years with a mean of 37 years

Type of accident The fracture was sustained in traffic accidents in 13 cases in high energy industrial accidents in 4 cases and in low energy domestic accidents in 3 cases Since high velocity impacts predominated many of the patients sustained multiple injuries one out of two patients had severe injuries in other gross body areas

Types of fractures as delineated from the radiographs have been compiled in Figure 1 Nine fractures were comminuted and 5 of these extended into the knee joint In this series the conjoined metaphyseal and condylar fractures were all compound an injury typically encountered in motorcyclists The commonest fracture was the metaphyseal transverse or short oblique fracture (13 cases)

Indications for operative treatment were as follows (1) intra articular bursting fracture of the metaphyseal and condylar region with poor alignment of the joint surfaces (5 cases) (2) severe comminution or severe displacement of metaphyseal fracture (9 cases) and (3) multiple injuries to other gross body areas complicating nursing in balanced traction (6 cases)

Fractures with slight displacement and no comminution were treated non-operatively in balanced traction (19 cases during the same period) Thus the operatively treated series included no spiral fractures of the type encountered in elderly women after slipping or stumbling An attempt to compile a control series failed because of discrepancies in severity between operatively and non operatively treated fractures.

	METAPHYSEAL FRACTURES		CONJOINED METAPHYSEAL AND CONDYLAR FRACTURES
NUMBER OF FRACTURES	13	3	5
COMPOUND FRACTURES	0	0	5
MULTIPLE INJURIES TO OTHER GROSS BODY AREAS	4	2	4

Figure 1 Type of fracture and incidence of multiple injuries in 20 patients with 21 fractures of the distal third of the femur treated by AOI osteosynthesis Note the preponderance of severe injuries in the group with intra articular fractures

Osteosynthesis was performed on the day of admission in 3 cases because of extensive soft tissue lesions in the knee region In the other cases primary treatment consisted of balanced traction until the tissue swelling around the fracture had subsided Osteosynthesis was undertaken on the 9th day on average after the accident

The operative technique was that advocated by Muller et al (1965) involving a posterolateral incision and fixation of the fragments with the AOI armamentarium In fractures through the condylar region the incision was extended down to the tibial tubercle This ample exposure proved advantageous for reconstruction of the joint surface and for adequate repair of the damaged suprapatellar pouch

Single or double straight compression plates were used in 15 fractures and an L-compression plate in 6 fractures No plaster immobilisation was used postoperatively except in cases with extensive soft tissue injury or concomitant injuries to the same limb

Postoperative physiotherapy was started early and intensified when wound healing was completed The patients were allowed out of bed on the 4th to 7th day postoperatively and encouraged to move around on crutches Training was continued for several months after hospital treatment under the supervision of a physiotherapist Light weight bearing (10–15 kg) was included early in the programme whereas full weight bearing was postponed for several months

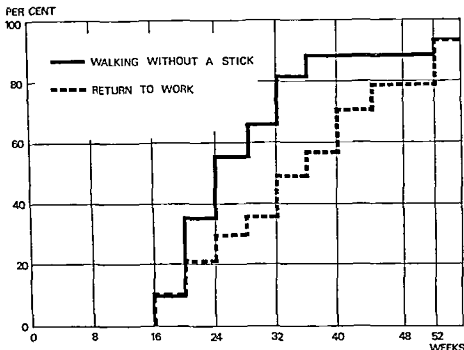


Figure 2 Time interval between operation and ability to walk without a stick and return to work after AOI osteosynthesis of fractures of the distal third of the femur Walking ability and return to work are expressed in cumulative percentages

All cases were followed until the end of treatment In addition the patients were summoned to a follow up examination one year or more after the operation Of the 20 patients 1 had died of a concomitant head injury 2 of other diseases and 1 did not attend the examination An end result was thus obtained in 16 out of 17 patients alive

RESULTS

Internal fixation rendered the fractures stable in all cases Clinical and radiographic appraisal of fracture union was therefore inconclusive and healing had to be assessed by functional results The following criteria were chosen for further analysis (1) the range of movement of the knee joint (2) the time interval between operation and ability to walk without a stick and (3) the time interval between operation and return to work

Range of movement of the knee joint At follow up examination the range of movement was evaluated as good with full extension and



Figure 3 Comminuted closed metaphyseal fracture of the femur, with additional fracture of the patella (a). AOI osteosynthesis with double plates resulted in functional (and radiological) union within 20 weeks. At follow up full extension and flexion of the knee, undisturbed walking but occasional pain from post-traumatic osteoarthritis of the patellofemoral joint (b)

flexion not limited by more than 10 degrees in 9 out of 16 patients 1). Five of these patients considered their knees normal, the rest had occasional pain in the joint region after strenuous effort (cf. Figure 3). One patient was unable to bend his knee to 90 degrees (range 0-80 degrees) owing to osteitis and delayed union of the fracture.

Avoidance of postoperative immobilisation and early joint exercises resulted in rapid improvement in the knee joint movements, although considerable stiffness was invariably observed in the initial postoperative stage. Thus all patients had poor knee joint mobility for 4 weeks after the operation. After this the range of movement increased rapidly, reaching fair readings within 20 weeks in all but two patients. In four cases normal knee movement was recorded within 16 weeks.

Experiences with these cases indicate that the importance of early

1) The evaluation of residual joint stiffnes closely followed the criteria proposed by Nicoll (1964):

Good = Full extension, flexion not limited by more than 10 degrees

Fair = Any loss of extension or loss of more than 10 degrees of flexion

Poor = Inability to flex the knee to 90 degrees



Figure 4 Comminuted compound intra articular fracture of the condylar region (a) treated with an L shaped compression plate Twelve weeks after the operation ability to walk without a stick and a further eight weeks later ability to ski At follow up normal function of the knee (b)



Figure 5 Comminuted compound conjoined fracture of the metaphyseal and condylar regions of the right femur sustained in a motor-cycle accident (a) On admission no peripheral pulses could be traced but arteriography revealed preserved continuity of the femoral artery (b)



Figure 5 (continued). The fracture was stabilized with an L-shaped plate, the femur deliberately shortened 4 cm and the bone defect filled with bone chips (c). Ten months after the accident a compensatory subtrochanteric shortening osteotomy of the left femur was performed and a further 22 months later the plate was removed from the right femur. At follow-up three years after the accident: ability to walk without a stick without noticeable limping (d). The knee was free from pain with a fair range of movement (0–90 degrees). Progressive post-traumatic arthritis is to be expected.

muscular exercise should not be overestimated; the final result was far more dependent on accurate realignment of the fragments and accurate reconstruction of the concomitant soft tissue injury.

Walking ability. Three patients were excluded from the results compiled in Figure 2 [1]). Of the remaining 13 patients, 11 were able to walk without a stick within 12 months after the operation. One patient, unable to walk without a supporting cane, was still under treat-

The omitted cases were: One patient with comminuted acetabular fracture, 1 patient with congenital luxation of the hip and 1 patient with bilateral degenerative osteoarthritis of the hip. But the diagram does include the following patients with concomitant injuries to the lower limbs: 2 cases with fracture of the tibia, 1 case with operatively treated total luxation of the contralateral knee joint, 1 patient with non-operatively treated ligamentous rupture of the contralateral knee joint and 1 patient with bimalleolar fracture.

ment (Figure 5) and the other was suffering from delayed union following osteitis

Squatting was normal in 7 patients and moderately restricted in 4

Walking ability was achieved to a similar extent in both metaphyseal and condylar fractures The majority of cases were able to walk without a stick within 6 months Stability of the fracture area absence of pain and rapid improvement in the range of knee movement undoubtedly contributed to the early recovery seen in many cases

Return to work (Figure 2) All but two patients had resumed work within one year after the operation The mean time of sick leave was 37 weeks and in cases without concomitant injuries 27 weeks

Complications There was one case with osteitis following osteosynthesis of a closed fracture in the metaphysis

A 51 year old male pedestrian was hit by a car and sustained fractures of the left femur and left lower leg in addition to brain concussion The femoral fracture was treated with double straight plates and the patient made an uneventful recovery Six months later signs of infection appeared and a fresh discharging sinus opened in the lower third of the thigh Irrigation and subsequent removal of the metallic implant were followed by closure of the sinus The fracture eventually united

No failure of the metallic implants or loosening of the material used in the osteosynthesis occurred In one case a new traffic accident caused bending of double straight plates implanted three months previously New plates were installed and the fracture united uneventfully

All fractures united

DISCUSSION

Conservative treatment is commonly accepted for distal femoral fractures In the series of Stewart et al (1966) comprising 422 fractures the result in 144 patients treated by closed methods and followed for one year or longer was excellent or good in 67 per cent and poor in 33 per cent The results of operative treatment have been impaired by a high rate of complications Neer et al (1967) reported postoperative osteitis in 40 per cent and Stewart et al (1966) delayed union or non union in one patient out of three

Perusal of current reports reveals that in the conservatively treated series the poor results are predominantly due to the fractures with gross comminution and derangement of the articular joint surfaces

Here prolonged immobilisation gives rise to residual joint stiffness and poor alignment of the fragments causes post traumatic arthritis In severe fractures, therefore operative treatment is indicated

It emerges from the present series that operative treatment affords good results in the majority of cases provided that stable osteosynthesis is achieved The internal fixation obtained with the AOI armamentarium was in all cases remarkably stable and proved reliable even in cases with gross comminution of the fracture The most gratifying results were in fact obtained in the severe fractures where treatment with closed methods would have been protracted and few if any alternative methods of internal fixation were available

Notwithstanding the dangers inherent in the AOI technique of internal fixation should not be forgotten The technique is difficult and requires a surgical team well trained in this type of surgery The extensive exposure and the sometimes several hour procedure increase the risk of postoperative infections Evidently fractures of slight to moderate severity are still best treated by non-operative methods Until further reports have emerged AOI osteosynthesis of fractures of the distal third of the femur should be confined to severe fractures complicated by gross comminution derangement of the condylar area and extensive soft tissue injury and for patients with multiple injuries where the plan of treatment as a whole demands internal fixation in order to facilitate appropriate nursing of the patient

SUMMARY

The results after internal fixation with straight or angled AOI compression plates have been analysed in 20 patients with 21 fractures of the distal third of the femur The fracture was compound in 5 cases and comminuted in 8 The most frequent causes were traffic accidents and similar high-energy impacts severe injuries to other gross body areas were encountered in one out of two patients

Sixteen of the seventeen patients still alive attended a follow up examination one year or more after the operation The range of knee movement was good in 9 patients fair in 5 patients and poor in 1 When biassing injuries were excluded all but 2 patients were able to walk without a stick within 12 months postoperatively most of these within 6 months All but 2 patients had resumed work within one year after the operation

There was one failure due to postoperative osteitis

No failures resulted from the metallic implants or loosening of the material used in the osteosynthesis

All fractures united

It is concluded that AOI osteosynthesis affords reliable internal fixation of fractures of the distal third of the femur Its use should be restricted to fractures of considerable severity and to selected cases among patients with multiple injuries

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Institute of Orthopaedics Oswestry England

SUB PERIOSTEAL GANGLIA

Neville R M Kay

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Ganglia or synovial lined cysts are ubiquitous Seymore (1968) and Crabbe (1966) both reported cases of intraosseous ganglia Woods (1961) described seven cases of synovial lined cysts in close relation ship to normal joints and Fisk (1949) described a case of recurrent ganglia of the tibia producing radiological absorption of bone Carp & Stout (1928) mention that ganglia located in the periosteum have been reported and Byers & Wadsworth (1970) report four cases

CASE HISTORY

A 36-year old male presented in clinic complaining of swelling and aching of the right leg Six years previously he had noticed a small swelling about the size of a pea two fingers below the tibial tubercle on the subcutaneous surface of the tibia No history of trauma can be recalled and the swelling was ignored until it became painful and swollen and prompted his first attendance at the outpa tient clinic His symptoms rapidly settled down without specific treatment Over the ensuing years he had no further trouble but noticed that the swelling gradually increased in size spreading down the subcutaneous surface of the tibia His second presentation at clinic was motivated by anxiety as to the nature of the swelling

Clinically

Clinically there was an irregular swelling some 5 cm long and of 2 5 cm wide over the upper part of the subcutaneous surface of the tibia This swelling was not attached to the skin did not subside with pres sure or elevation of the leg and was fluctuant in parts No glands were palpable in the groin and pulses in the leg were normal

Investigations

ESR Latex Test for rheumatoid arthritis serum uric acid and white cell count were all normal X ray of the tibia showed no evidence of bone cysts

Figure 1 Strip of periosteum containing multi loculated cysts being removed from subcutaneous surface of tibia



Figure 2 Histology Section of specimen (× 6) showing large cystic area and several smaller cystic areas in thickened periosteum

Operation

Through a longitudinal incision the swelling was exposed and found to be a series of multi loculated ganglia of varying size and containing typical ganglion fluid These cysts arose from the deeper layers of the periosteum and lifted it off the tibia Some of the larger cysts had produced small pressure indentations in the tibia but at no site was the tibia actually invaded No communication with the knee joint or the superior tibio fibular joint was found on exploration A segment of periosteum with the attached cysts some 15 5 cm long and 3 7 cm wide was excised and the wound closed

Post operatively

Post operatively there were no complications and there has been no further recurrence at follow up eighteen months later

DISCUSSION

Since the time of Ellers (1746) the aetiology and nature of ganglia has been in dispute Initially believed to be due to a herniation of joint cavity or tendon sheath Clarke (1908) regarded them as cystic neoplasms of connective tissue origin Campbell (1963) notes that some ganglia are discrete cysts lined with synovium and attached by a ped icle to synovial sheaths whereas others are poorly circumscribed lack a well defined lining and are usually found in the vicinity of large joints The origin of such ganglia has been attributed to displaced synovial tissue the extravasation of mucin into the periarticular tis sues or due to mucoid degeneration in connective tissues The fibroblasts produce intercellular mucin which forms pools that coalesce to form one or several cysts The surrounding tissue is compressed by the accumulating fluid but there is also a fibroblastic prolification and collagen formation which results in a fibrous wall

The findings of synovial cysts within bone whose nearby joints were not diseased produced yet more speculation Crabbe (1966) regards intraossesous ganglia as comparable with other ganglia points out the close histological similarity and states that intraosseous ganglia develop in close relationship to the insertion of ligamentus structures in bone

However Fisk (1949) reports the case of a 44 year old airman with radiological evidence of reabsorption of the tibia which was due to a recurrent ganglion He concluded that in his case the ganglion had

arisen from the periosteum and caused erosion of the bone before bursting into the subcutaneous tissue and presenting clinically

However in one case where the underlying bone was examined histologically Byers & Wadsworth (1970) demonstrated that bone is not always reabsorbed beneath a periosteal ganglion and may react by producing new bone

The possibility of synovial bone cysts being derived from metaplasia of bone as suggested by Hick (1956) cannot be excluded and gains support from Byers & Wadsworth who state that 'the lesions in bone seem to depend in the first instance on the development of focal marrow fibrosis within which the degenerative process takes place Nevertheless intraosseous ganglia in bone near osteoarthritic joints may be due to the extrusion of synovial fluid from the joint through microfractures (Landells 1953) The recognition of ganglia arising from the periosteum and producing pressure indentation on the bone below raises the possibility that some intraosseous ganglia may arise from the periosteum

This appears to be a reasonable hypothesis when Fisk s case is considered in conjunction with the case described above and is reinforced by the illustration of the intraosseous ganglia shown by Seymore which has a well developed stalk It is therefore suggested that intraosseous bone ganglia may also arise from the periosteum under the stimulus of factors yet unknown Enlargement of the cyst can cause pressure absorption of the bone below the cyst which gradually sinks into the bone eventually loses its connection with the periosteum and thus appears to be a truly intraosseous ganglion

SUMMARY

A patient with a sub periosteal ganglion presenting as a multiloculated subcutaneous cystic swelling over the shaft of the tibia is described No connection between the surrounding joints and the ganglion was found at operation The aetiology of ganglia is briefly reviewed and three mechanisms whereby intraosseous ganglia may arise are discussed

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The Orthopaedic Hospital Department I Copenhagen Denmark

AMPUTATION IN CHILDREN

A follow up of 74 children whose lower extremities were amputated

KNUD JØRRING

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The object of the present study was to obtain an impression of the incidence of complications in patients who had been exposed to amputation during childhood and also to learn how these children later had adapted themselves to society

MATERIAL

The series comprised 74 surviving patients to whom leg prostheses had been fitted prior to their 16th year all patients had been seen in the Orthopaedic Hospital in Copenhagen in the period from 1899 to 1964

Sixty four of the patients were examined by the author ten refused to co operate at the follow up and effects in the latter cases had therefore to be analysed exclusively on the basis of data included in the case records

Amputation was bilateral in eight cases and hence the examination included 82 extremities Any difference between right and left sides was not demonstrable

Table 1 Specification of terms of follow ups of 74 children exposed to amputation in eight cases to bilateral amputation of lower extremities

Term of follow ups	No of amputations
6–10 years	6
11–20 years	18
21–30 years	22
31–40 years	14
41–50 years	9
51–60 years	10
61–70 years	2
71 years	1
	82

Table 2 Indications for 82 amputations of lower extremities in children in relation to sex and age

	In total	Boys	Girls	< 2 years	2–6 years	> 6 years
Trauma	46 (4)	36 (4)	10	2	21	23
Traffic	22					
Farming	14					
Sundry	10					
Congenital deformities	26 (4)	13	13 (4)	0	7	19
Infection	8	5	3	0	5	3
Tuberculosis	4					
Osteomyelitis	4					
Tumour	2	1	1	0	1	1
No of amputations	82 (8)	55 (4)	27 (4)	2	34	46
No of patients	74	51	23			

Figures in brackets denote bilateral amputations

At the time of follow up ages of patients ranged from 20 years up to 74 years Follow up periods covered at least six years at most 71 years Lengths of follow up periods are specified in Table 1

Table 2 represents an analysis of indications for amputations together with the distribution according to age and sex of patients

The level at which extremities were amputated is apparent from Table 3 In two cases the hip joints were exarticulated on account of tumour growths

RESULTS

Data on primary complications to the surgical measures were available in the case of eight patients (11 per cent) In five of these it had been a matter of infection in three of delayed wound healing

Data on secondary complications are recorded in Table 4 Among 74 children 29 had been exposed to repeated surgery at later stages in about half of these surgery had been repeated even several times

Table 5 illustrates the problem of overgrowth in relation to age of patients this problem is particularly conspicuous if young amputees are concerned

Types of prostheses applied are specified in Table 6

Since 1933 all expenses in connection with the prostheses have been defrayed by the Government via the Board of Disablement Insurance

Throughout childhood patients must have their prostheses re

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The Orthopaedic Hospital Department I Copenhagen Denmark

AMPUTATION IN CHILDREN

A follow up of 74 children whose lower extremities were amputated

Knud Jørring

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The object of the present study was to obtain an impression of the incidence of complications in patients who had been exposed to amputation during childhood and also to learn how these children later had adapted themselves to society

MATERIAL

The series comprised 74 surviving patients to whom leg prostheses had been fitted prior to their 16th year all patients had been seen in the Orthopaedic Hospital in Copenhagen in the period from 1899 to 1964

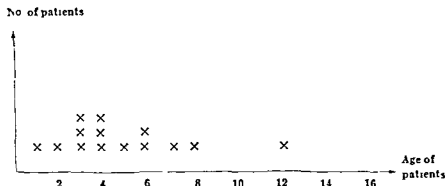
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Table 5 Age of children at the time of amputation of lower extremities followed by overgrowth of bone



The author has personally examined the pattern of gait in 64 of the patients Twenty patients limped to a certain degree although their gait subjectively and objectively was rather satisfactory Five patients walked poorly limping was pronounced and their walking capacity ranged below 200 m In the latter cases lesions had been of complicated nature polio marked scoliosis arthrodesis involving the hip of the intact joint pronounced congenital shortening of the contralateral leg (bilaterally amputated) furthermore one patient "sagged to his too short prosthesis having accustomed himself to it however he did not want it replaced

In the course of study it was endeavoured to obtain an opinion of the patients adaptation to society Their marital status did not deviate from that among the population in general The number of childless marriages did not either (10 per cent) Fourteen patients had received an education within the compass of the Public Rehabilitation Society Eleven had received rehabilitation relief Thus one third of all patients had been assisted but two-thirds had been able to manage on their own (assisted by their relatives)

Among the 74 patients nine received disablement pensions and two received disablement benefits

Occupations of patients were collated with occupations of their supporters the results appear from Table 7 The tendency is apparently that the children manage better than their supporters During the period of time covered by the study the proportion of the population to receive an education had reached a high level as a

Table 6 Types of prostheses fitted to children 82 amputations of lower extremities

Canadian prosthesis used in cases of exarticulation of hip joints	2
Femoral contact prosthesis	14
Femoral suction prosthesis	11
Conventional below knee prosthesis	26
Patellar tendon bearing prosthesis (PTB)	21
Syme's and hind foot prosthesis	8
	82

result of sociological evolution Thus this feature need not be related to the handicaps of patients, it is rather an expression of the general change in the composition of Danish society

DISCUSSION

Amputation in children is not common In a series originating from a clinic supplying prostheses Jansen (1960) observed that 16 per cent were children whose legs had been amputated during a study of the population in Gothenburg Hansson (1964) found that 2 per cent were children of this type among a total of 586 amputees

With a view to obtaining a sufficiently large series of child amputees two courses may be followed either examination of patients treated in several different centres (Clippinger et al 1969) or selection of series that are representative of long periods of time The latter course has been preferred in the present study

The author has personally examined 64 patients out of 74 (87 per cent) at follow ups this percentage is considerably higher than that otherwise examined by investigators in other countries in their studies based on long periods of observation (Lambert et al 1969)

Table 7 Occupations of patients collated with occupations of their supporters

	Untrained	Intermediate degree of training	Specially trained
Occupation of supporter	22	42	9
Occupation of amputee	10	49	15

Indications for amputations in children included primarily traumatic lesions although congenital malformations also played a certain role interventions indicated by infections or tumours were rather un common

The series comprised twice as many boys as girls the difference being particularly conspicuous when amputations due to traumata were concerned

Intervention by tourniquet was not contra indicated in any of the cases Amputations due to infection were all performed more than 30 years ago

The series comprised only two cases in which amputations were required on account of malignant tumour growths (sarcoma and fibrosarcoma) No patients other than those whose prostheses had been fitted during childhood and who were still alive in 1964 have been included if all children to whom prostheses had been fitted during the period from 1899 to 1964 had been included amputations due to tumour growths would have been more numerous On the other hand the number of patients to be examined by the author would have been much smaller because most of the children in whom amputations had been indicated by malignant growths would have been dead at the time of follow up

Below knee amputations were twice as numerous as above knee amputations The reverse applied to the series of adult patients studied by Kolind Sorensen (1970)

The present study confirmed that phantom limb pains were im material if amputations dated back to childhood (Aitken & Frantz 1953) which is in contrast to findings obtained by Villars Lunn (1948) in his study of a series comprising children and adult patients among whom 20 per cent suffered constant or frequently occurring phantom limb pain

The author learned from some of the patients how they at first after the prosthesis had been fitted continued to dream that they were walking on their own legs but after they had accepted their handicap completely they were using their prostheses even in their dreams

Among the old patients were quite a few who had experienced periods during which their prostheses had been made of cardboard these had later been replaced by prostheses of the "pirate s leg type and the permanent prosthesis had not been fitted until they were about 14 years old By now this type of bandaging has been abandoned

it is considered of value to provide prostheses which are immediately acceptable by the children as well as by their parents (Aitken & Frantz 1964)

In the case of above knee amputations Bomfim (1969) suggested having prostheses fitted while the children concerned were at ages between 18 months and two years at least they should not be more than four years old below knee prostheses should preferably be fitted while the children were at ages between nine and twelve months

Immediate postsurgical fitting has not been of topical interest in the present study This procedure, which was introduced by Weiss in 1963 at the IX World Congress of the International Society for Rehabilitation of the Disabled has later been found to be relevant in cases of children (Hierton et al 1967) Children are particularly suited for 'intermediate fitting' owing to their excellent vascular supply On the basis of psychological deliberations this procedure has been generally adopted by now whenever children are concerned (Chppinger 1966)

Bones in children are immature and the programming of amputation should never disregard the problem of growth in length, furthermore, care should be taken to preserve as many as possible of the epiphyseal lines (Aitken 1963)

Even though children usually escape inconveniencing scar formation neuroma and phantom limb pain during the healing process of the stump one problem was seen to predominate in cases of children whose legs had been amputated namely overgrowth In quite a few of the cases surgery had to be repeated because bones were found to grow at a rate higher than that of the soft tissues In general surgery had to be repeated within a few years, and occasionally repeated surgery was required even two or three times

Owing to the problems involved in skin affection two patients were unable to use prostheses for about six months Bursa formation associated with an occurrence of abscesses required frequently repeated surgery distribution of the latter according to time was uniform throughout the period of follow up surgery was repeated even as late as 42 years after the primary intervention

A precise psychological and social analysis of the children s environments is required if late results are to be optimal (Steensma 19.9) Intimate co-operation with the parents concerned is also of decisive value (Fishman 19.8)

CONCLUSION

The study here submitted comprises 74 patients who prior to their 16th year had been provided with prostheses the prostheses were fitted in the Orthopaedic Hospital in Copenhagen during the period from 1899 to 1964

The series comprised 69 per cent boys traumatic lesions exclusively accounted for this predominance of boys Below knee amputation was most common which is in contrast to features otherwise observed among adult amputees in whom above knee amputation is most generally encountered

Secondary complications were numerous and repeated surgery was required in 29 of the cases (39 per cent) Overgrowth was seen mainly when amputation had been done early in life (children below the age of six years)

All of the patients used their prostheses and in general patterns of gait were satisfactory

It was attempted to form an opinion of the social standing of the patients and their supporters and it appeared as though the social standard had advanced among amputees whose level of education seemed to be higher than that of the older generation since the study covers a rather long period of time however this feature may be attributable to the over all advance in social standing which has occurred in Danish society

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Department of Orthopaedic Surgery U, University Hospital, Copenhagen, The Directorate of Employment Injuries Insurance, Copenhagen, and Surgical Department D, Glostrup Hospital, Copenhagen

PSEUDARTHROSIS OF THE LATERAL MALLEOLUS

Otto Sneppen

Accepted 2[illegible] iv 71

Although the incidence and prognostic significance of medial malleolar pseudarthrosis has been fairly well elucidated (Sneppen 1969), far less is known about pseudarthrosis of the lateral malleolus. The explanation is no doubt primarily that lateral malleolar pseudarthrosis is relatively uncommon, so that only a few cases are on record.

In 1930 Lützeler published the first case of non-union of lateral malleolar fracture, and Rostock in 1938 added four, on which, however, the follow-up was very brief. Since then a number of authors (Hallock 1945, van de Voorde et al. 1950, Fackert 1954, Cohen & Foultz 1960, Jones & Neal 1962, Cave 1965, Pouyanne et al. 1965, Pizio & Mazur 1968) have been able to submit single or a few cases, bringing the total number of published cases up to 35.

Moreover, the great majority have only a very brief follow-up period, so that the diagnosis of pseudarthrosis is based merely upon the absence of bony union a few months after the accident.

A very few authors have published materials which permit an assessment of the incidence at which pseudarthrosis occurs after ankle fractures involving the lateral malleolus. These materials are listed in Table 1, from which it is apparent that pseudarthrosis of the lateral malleolus seems to develop in about one per cent of conservatively treated fractures.

Only a few have studied the prognosis of lateral malleolar pseudarthrosis. Mendelsohn (1958) and Cave (1965) believed that this complication made for a poor prognosis of the ankle fracture, but this assumption was based upon only a few cases. Therefore the prognostic role of lateral malleolar pseudarthrosis must be said to be unknown in all essentials.

On this background the present study was performed in an effort

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With Bohler's definition the claim of a minimum gap of 3 mm excludes cases with a less but distinctly open fracture gap perhaps after several years follow up and with Mendelsohn s definition many cases with a wide fracture gap cannot be included merely because the fracture surfaces are not sclerosed

A sufficiently flexible definition can apparently be based only upon the finding of lacking radiographic evidence of union after a suitable follow up period whether this period is fixed as 6 months or more

In the present study the following definition of lateral malleolar pseudarthrosis was used Absence of bony union at least 9 months after a fracture affecting the area from about 2 cm proximal to the malleolar base to the malleolar apex presupposing that the malleolar fragment is at least 5 mm in diameter Oblique fractures extending from the malleolar base more proximally than the named 2 cm are included On the other hand minor shell shaped chips found at times in connection with ligamentous avulsions are excluded

MATERIAL

The basic materials are as follows

1 All ankle fractures notified to the Directorate of Employment Injuries Insurance in Denmark during the period 1945–1966 excluding cases not recognized as coming within the Employment Injuries Insurance Act
2 All cases of lateral malleolar pseudarthrosis treated in the Orthopaedic Hospital Copenhagen during the Period 1934–1968
3 All cases of lateral malleolar pseudarthrosis treated in the Department of Orthopaedic Surgery U of the University Hospital Copenhagen during the period 1964–1969

These materials included a total of 25 patients with pseudarthrosis of the lateral malleolus 16 derived from the insurance series 2 from the Orthopaedic Hospital Copenhagen and 7 from Department U of the University Hospital Copenhagen

Out of these 25 patients 1 underwent talo crural arthrodesis and was therefore not included in the follow up study Out of the remaining 24 patients 23 (96 per cent) were examined by the author

The only patient who was not seen at follow up had gone to Australia and was contacted by letter He reported that in spite of fairly heavy standing work he had only occasional negligible complaints in the form of slight fatigue in the ankle

Table 2 Incidence of lateral malleolar pseudarthroses in relation to morphology of ankle fracture The table lists only the insurance series

Type of fracture	No of cases	No of lateral malleolar pseudarthroses
Fibula	2445	3 (0 1 %)
Fibula + margo posterior tibiae	330	0
Fibula + malleolus medialis	1128	9 } *13 (0 7 %)*
Fibula + malleolus medialis + margo posterior tibiae	766	4 }
Others	91	0
Total	*4760*	*16 (0 3 %)*

Of the 23 patients seen at follow up 2 were females and 21 males At follow up the patients ranged in age from *20* to *68* years average age 45 years

The follow up period from the time of the accident until follow up ranged from 3 to 23 years average 9 6 years

Aetiology and Incidence

Table 2 gives the incidence of lateral malleolar pseudarthroses in relation to the morphology of the fracture It will be noted that the table comprises exclusively the insurance series which included 4760 ankle fractures involving the fibula Among these cases pseudarthrosis occurred in 16 (0 3 per cent)

It may be seen from the table that whereas ankle fractures which did not involve the medial malleolus showed an incidence of lateral malleolar pseudarthrosis of 0 1 per cent ankle fractures involving the *medial malleolus showed an incidence of pseudarthrosis of* 0 7 per cent The difference is significant ($p < 1$ per cent)

Thus the medial stability of the ankle seems to influence the incidence at which pseudarthrosis of the lateral malleolus occurs

In Table 3 the 23 cases of lateral malleolar pseudarthrosis are distributed by type and stage of fracture according to the genetic classification of fractures introduced by Lauge Hansen (1942) The table also gives the corresponding distribution in a control material Clearly the distribution in the pseudarthrosis material differs mark

Table 3 Distribution of the lateral malleolar pseudarthroses of the follow up material by type and stage of fracture compared with the distribution in a control material of ankle fractures The control material is composed of the series reported by Lauge Hansen (1949) Bæk Kristensen (1953) Solonen & Lauttamus (1968)

Type of fracture	Stage	Lateral pseudarthroses	Control material
SA	I	9 (39 %)	62 (6 %)
	II	7 (30 %)	85 (9 %)
SE	II	1 (4 %)	201 (21 %)
	III	0	86 (9 %)
	IV	5 (22 %)	432 (45 %)
PA	III	1 (4 %)	102 (11 %)
Total		23 (100 %)	968 (100 %)

edly from that in the control material For instance 69 per cent of the lateral malleolar pseudarthrosis developed in cases with fractures of the SA type (supination fractures) whereas only 15 per cent of the control cases had developed from fractures of this type This difference in the incidence is highly significant ($p < 0.1$ per cent)

In other words especially the transverse avulsion fractures i e the



Figure 1 Lateral pseudarthrosis commonly follows upon fractures of the supination type In this case 11 year follow up period

Table 4 Position of talus and position of malleolar fragment in 23 cases of pseudarthrosis of the lateral malleolus The table lists the follow up material

	Malleolar fragment *in situ*	Malleolar fragment displaced	Total
Talus *in situ*	12	5	17
Talus varus tilted or medially subluxated	1	3	4
Talus valgus tilted or laterally subluxated	0	2	2
Total	13	10	23

supination fractures, of the lateral malleolus predispose to pseudarthrosis in this site (Figure 1)

The position of the talus and of the lateral malleolar fragment in the cases with pseudarthrosis is illustrated by Table 4 Out of the 25 cases 4 had varus displacement and/or medial subluxation of the talus (Figure 2) whereas only 2 had valgus displacement and/or



Figure 2 Pseudarthrosis distally in the lateral malleolus after a supination fracture Marked varus tilting of the talus 13 month follow up period



Figure 3 Spontaneous union of pseudarthrosis proximally in the lateral malleolus The picture on the left illustrates the status 1? months after the accident showing perhaps incipient union centrally in the pseudarthrosis The picture on the right shows the status 18 years after the injury

lateral subluxation of the talus Accordingly there seems to be a certain relationship between varus displacement and/or medial subluxation of the talus and lateral malleolar pseudarthrosis

Prognosis

The influence of lateral malleolar pseudarthrosis upon the long term prognosis may be assessed on the basis of the 23 followed cases having this complication

At the time of follow up 11 of the 23 pseudarthroses had undergone bony union 3 of them after operative treatment of the pseudarthrosis Twelve were still ununited at the time of follow up

Among the 20 cases of lateral malleolar pseudarthrosis not treated by operation 12 were localized close to the malleolar apex and among these 12 cases only 3 had undergone spontaneous union On the other hand 5 out of 8 cases of a more proximal localization had united (Figure 3)

Table 5 Radiological findings in 23 cases of pseudarthrosis of the lateral malleolus The table lists only the follow up material

Radiological result	No osteo arthritis	Mild or severe osteoarthritis	Total
Good (no displacement)	10	4	14
Fair (negligible displacement)	3	0	3
Poor (marked displacement)	0	6	6
Total	13	10	23

On the basis of the present definition of lateral malleolar pseud arthrosis then this pseudarthrosis showed a marked tendency to spontaneous union This tendency seems to be particularly marked for pseudarthroses localized proximally in the malleolus

The X ray findings in the 23 cases of pseudarthrosis are apparent from Table 5

The classification of the radiological result shown in this table was based on the following criteria

A *good radiological result* means no radiologically demonstrable displacement.

A fair radiological result means a maximum forward or backward displacement of 2 mm of the medial malleolus Maximum backward displacement of the lateral *malleolus 2 mm Maximum elevation of posterior tibial fragment 2 mm*

A poor radiological result means a displacement more marked than mentioned above

From the table it is apparent that the *incidence of osteoarthritis* was relatively low in cases with a good or fair radiological result there being only 4 cases among 17 On the other hand all 6 patients with a poor radiological result had osteoarthritis of the talo crural joint One of these 6 patients also had subtalar osteoarthritis

Out of the 13 cases without osteoarthritis 4 showed the pseud arthrosis to be localized at the malleolar base 9 more distally in the malleolus

The fairly low incidence of osteoarthritis in cases with a good or fair radiological result indicated that the lateral malleolar pseud arthrosis is not a factor in the development of osteoarthritis in the *talo crural joint* To investigate this aspect in some more detail the occurrence of osteoarthritis in the united and in the ununited cases of lateral malleolar pseudarthrosis is compared in Table 6 No dif

Table 6 Incidence of osteoarthritis in 17 cases of lateral malleolar pseudarthrosis with a good or fair radiological result

Status of pseudarthrosis	No osteoarthritis	Mild osteoarthritis	Severe osteoarthritis	Total
United	6	1	1	8
Ununited	7	1	1	9
Total	13	2	2	17

ference is seen between the two groups a further indication that lateral malleolar pseudarthrosis plays no role in the development of osteoarthritis (Figure 4)

In 4 cases the *mobility of the malleolar fragment* was studied in anteroposterior X rays with the foot in maximum supination and in maximum pronation but only one case gave an impression of mobility (Figure 5) In this case the follow up period was 13 years but there were no radiological signs of osteoarthritis

To investigate further whether lateral malleolar pseudarthrosis might have any influence upon the prognosis of the ankle fracture the clinical results in united and in ununited cases are compared in Tables 7 and 8 These tables include only cases with a good or fair



Figure 4 Pseudarthrosis of the lateral malleolus 13 year follow up period No osteoarthritis



Figure 5 Lateral malleolar pseudarthrosis with a mobile malleolar fragment No osteoarthritis 13 year follow up period

radiological result and without osteoarthritis as this gives a clearer picture of the symptoms and signs of malleolar pseudarthrosis

The classification of the clinical result used in the tables is based upon the following criteria

A good subjective result means no complaints or mild complaints upon extra strain

A fair subjective result means more severe complaints on extra strain or daily mild complaints which however do not influence the patient s normal activity

A poor subjective result means more severe complaints than mentioned above

A good objective result means essentially normal objective findings

A fair objective result is taken to mean that at least one of the movements in the ankle or other joints of the foot is restricted to between one third and one half and/or about 1 cm muscular wasting of the lower leg or thigh No deformity of the foot or ankle Gait normal

A poor objective result is taken to mean a more restricted mobility or a more pronounced muscular atrophy than mentioned above or deformity of the foot or ankle or abnormal gait

It is evident from the tables that in this material there was no demonstrable difference in subjective or objective result between ankle fractures with lateral malleolar pseudarthrosis and corresponding ankle fractures without this complication

Table 7 Subjective result in cases with united and with ununited pseudarthrosis of the lateral malleolus
Only cases with a good or fair radiological result and without osteoarthritis are included

Status of pseudarthrosis	Subjective result			
	Good	Fair	Poor	Total
United	3	2	1	6
Ununited	5	1	1	7
Total	8	3	2	13

Table 8 Objective result in cases with united and with ununited pseudarthrosis of the lateral malleolus
Only cases with a good or fair radiological result and without osteoarthritis are included

Status of pseudarthrosis	Objective result			
	Good	Fair	Poor	Total
United	5	0	1	6
Ununited	6	0	1	7
Total	11	0	2	13

There was also no evidence to indicate that lateral malleolar pseudarthrosis gave rise to any characteristic symptoms or signs For instance among the cases listed in Tables 7 and 8 there were among 6 united cases 2 with instability or pain when walking on rough ground 2 with pain localized specially around the lateral malleolus and 2 with distinct tenderness on the lateral malleolus whereas among the 7 cases with persisting pseudarthrosis there was only 1 with instability and none with pain or tenderness localized particularly at the lateral malleolus

DISCUSSION

Mendelsohn (1958) and Cave (1965) claimed that lateral malleolar pseudarthrosis caused a poor prognosis As an explanation Cave

mentioned the pressure of the talus on the lateral malleolus when the foot is brought into pronation In this connection it must be borne in mind that during weight bearing in the upright position the lateral malleolus carries about one fifth of the talar pressure (Weber 1966) Therefore an ununited lateral malleolar fracture was supposed to entail considerable instability of the ankle joint leading to a poor prognosis

However that an intact lateral malleolus need not necessarily be a presupposition for a functioning ankle is shown by a publication by Campbell (1938) A patient who had undergone resection of the distal one fourth of the fibula including the lateral malleolus 20 years previously had only negligible complaints and no osteoarthritis Soustelle et al (1966) reported on a similar case in which a patient had been subjected to resection of the lateral malleolus on a level with the talo crural joint Three years later there were no complaints worth mentioning no instability and no signs of osteoarthritis

In accordance with the last mentioned findings the present study appears to show that pseudarthrosis of the lateral malleolus does not at long sight exert any influence upon the incidence of osteoarthritis or upon the clinical appearance In other words lateral malleolar pseudarthrosis does not influence the long term prognosis of the ankle fracture

SUMMARY AND CONCLUSION

On the basis of a review of 4760 consecutive ankle fractures involving the fibula and a follow up examination of 24 cases of pseudarthrosis of the lateral malleolus average follow up period 9 6 years the following conclusions are drawn

Re aetiology and incidence

1 The medial stability of the ankle the medial malleolus is an important factor in the aetiology of lateral malleolar pseudarthrosis This is manifest in a considerably higher incidence in ankle fractures involving also the medial malleolus (Table 2)

2 Ankle fractures of the supination type relatively often give rise to pseudarthrosis of the lateral malleolus (Table 3)

3 Varus displacement and medial subluxation of the talus are relatively common among cases of pseudarthrosis of the lateral malleolus and are perhaps factors in its aetiology (Table 4)

Re prognosis

1 Lateral malleolar pseudarthrosis shows a marked tendency to spontaneous union in particular when localized proximally in the malleolus
2 Lateral malleolar pseudarthrosis does not predispose to osteoarthritis in the ankle joint (Tables 5 and 6)
3 Lateral malleolar pseudarthrosis does not influence the long term prognosis of the ankle fracture (Tables 7 and 8)

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Directorate of Accident Insurance and Surgical Department D Glostrup Hospital and Orthopaedic Department U Rigshospitalet Copenhagen Denmark.

TREATMENT OF PSEUDARTHROSIS INVOLVING THE MALLEOLUS

A postoperative follow-up of 34 cases

OTTO SNEPPEN

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Surgical treatment of pseudarthrosis involving the malleolus had apparently not been attempted until late in the 19th century (Hueter 1877 Louart 1896 Nasse & Borchardt 1901) and consequently such treatment had in principle to be based on the not too encouraging experience hitherto gained in the treatment of pseudarthroses at other sites especially in the long tubular bones

Indications for surgical treatment have varied parallel with variations in evaluations concerning the prognostic prospects of malleolar pseudarthrosis It is in particular the rather common pseudarthrosis of the *medial* malleolus that has been an object of discussion For instance several authors held that the prognosis of this type of pseudarthrosis was of severe nature and consequently also that operations should be performed on all cases Weigl (1949) and Bedogni & Bergami (1962) shared this point of view whereas Plaue (1967) argued that operation should be performed only in the case of young patients taking into consideration the involved hazards of arthrosis

Schmidt (1929) Felsenreich (1937) and Lange (1967) were of the opinion that surgical measures should be reserved for the rather uncommon "mobile pseudarthrosis although other types of the lesions were to be surgically treated only if symptoms were in evidence or specific conditions applied

According to Tager (1960) Harvey (1965) Fischetti & Savoini (1965) and Solonen & Lauttamus (1968) the factor "mobility" was not an adequate criterion on which to decide whether or not operation was indicated these authors preferred to operate on all cases

Table 1 Results obtained by surgical treatment of pseudarthrosis involving the medial malleolus

Author	Pre operative follow up	Pseudarthrosis no of cases	Postoperative osseous union no of cases	Comments
Weigl (1949)	?	2	2	Postoperative fixation of the foot in adducted position (relief of the deltoid ligament)
Kuntscher (1953)	5 months	1	1	
Laurent (1956)	10–70 months	3	3	
Galvante & Salvagini (1960)	2–24 months	5	3	Union is uncertain in the remaining 2 cases
Walter (1964)	5–13 months	3	3	Union not achieved until 4–6 months after operation
Total		14	12	

Surgical method Excision of fibrous tissue restoration of fracture surfaces and fixation of the fragment by bone peg or clamp

in which complaints were of severe character Plaue (1967) warned against the use of such an indication pointing out that fractures might be followed by sequelae other than pseudarthrosis

The *surgical methods* can be classified into different categories accordingly as bone grafts are applied or the pseudarthrosis is excised

It appears from Tables 1 2 and 3 that results to be obtained by the various methods had been encouraging even in cases in which bone grafts had not been applied and in those in which the pseudarthrosis had not been excised

It should be noted however that patients included in the series cited in the tables had been followed only for short periods of time prior to operation furthermore the results obtained in these series are probably optimal results since authors are not much inclined to submit reports of series in which poor results were obtained Actually several authors have mentioned that they abandoned one or the other type of operation because of the poor results obtained

Table 2 Results obtained by surgical treatment of pseudarthrosis involving the medial malleolus

Author	Pre-operative follow up	Pseudarthrosis no of cases	Postoperative osseous union no of cases	Comments
Andresen (1938)	?	11	10	Sliding bone graft
Banks (1949)	?	2	2	
Banchero & Rettagliata (1960)	?	2	2	
Tager (1960)	?	28	25	Fixation by heterologous bone
Fischetti & Savoini (1965)	ca 3 months	2	?	Block of spongious tissue from tibia in the defect of th pseudarthrosis Union not reliable until years later
Plaue (1967)	> 3 months	10	9	In the remaining c union occurred wit 11 months
Total		55	48	

Surgical method Excision of fibrous tissue restoration of fracture surfaces fixation of the malleolar fragment and application of bone grafts (inlay grafts bone pegs or bone chips)

Surgical methods other than those recorded in the tables have also been used For instance Weigl (1949) Lange (1951) and Walter (1961) fixed the malleolar fragment by a metal clamp designed by Zuelzer (1948 1951) and Kuntscher (1953 1962) designed an elastic spongiosa peg to be used for the same purpose Forgon & Berenyi (1958) preferred to have the malleolar fragment fixed by a crooked Kirschner wire that was drilled upward into the malleolus it penetrated on the reverse side of the tibial bone at which site an elastic device was fitted which exerted traction on the wire and thereby compression on the fracture

Table 3 Results obtained by surgical treatment of pseudarthrosis involving the medial malleolus

Author	Pre operative follow up	Pseudarthrosis no of cases	Postoperative osseous union no of cases	*Comments*
Rieunau & Gay (1956)	?	2	2	Large tibial graft of specific form applied as inlay graft
Berentey Somogyi & Peer (1956)	3–11 months	2	2	
Tos (1960)	20 years	1	1	
Fischetti & Savoini (1965)	ca. 3 months	3	3	
Total		8	8	

Surgical method *Fibrous tissue not excised application of bone transplants exclusively (inlay grafts)*

According to Rostock (1938) it might be recommendable to use drilling according to Beck s method throughout the early stages of the process of fibrous union Stotz (1943) abandoned this method however because it might fail to bring about union in many cases Bohler (1957) did not find drilling an adequate procedure either

If the malleolar fragments were sufficiently small it might be justified according to Stotz opinion (1943) to have them extirpated Boyd (1963) and Weber (1966) were also in favour of such treatment always provided that the proximal portion of the malleolus was *sufficiently large to keep the ankle joint mortise preserved*

It emerges from the numerous trials using different types of operation that the results obtained may not always have been as favourable as they seem to be according to Tables 1 2 and 3 it can hardly be denied that the basis on which to evaluate the relative value of operations might have been more reliable if less selected series had been reported above all if periods of observation prior to operation had covered intervals longer than six months Such series are scarce however and thus a comparison cannot be made

With a view *to elucidating the problems involved in a surgical* treatment of pseudarthrosis involving the malleolus a review shall

be given of results obtained in a series of surgically treated cases The patients concerned were followed for rather long periods of time prior to as well as after operation

In the present paper malleolar pseudarthrosis is interpreted as nonunion of malleolar fractures at least six months after the time of accident

AUTHOR S SERIES

The following series have served as a basis for the study

1 All surgically treated pseudarthroses of the malleolus developed after fractures of ankles notified to the Directorate of Accident Insurance in Denmark in the period from 1945 to 1966 16 cases

2 All cases of pseudarthrosis of the malleolus surgically treated in the Orthopaedic Hospital in Copenhagen in the period from 1934 to 1968 8 cases

3 All cases of pseudarthrosis of the malleolus which prior to 1969 had been surgically treated in other orthopaedic and surgical departments in Denmark 13 cases

The series comprise 37 lesions of ankles pseudarthrosis involving the medial or lateral malleolus was exposed to surgery on 38 occasions (on one occasion operation was performed on a bi malleolar pseud arthrosis) Operation on account of pseudarthrosis of the medial malleolus had to be repeated in one case and thus 39 operations were performed

The series comprise 10 female patients and 27 male Ages of pa tients at the time of accident varied from 10 years up to 72 years averaging 34 0 years

The pre operative follow up periods in all cases appear from Table 4 from which it will be seen that about 75 per cent of the cases were exposed to surgery at early stages In general the pre operative periods of follow up covered from six months up to 24 years averag ing 29 months

It applies to all cases that operation apparently had been indicated on account of rather severe subjective symptoms such as pain in the

Bispebjerg Hospital Department M Gentofte Hospital Department B Glostrup Hospital Departments A and D Kolding Hospital Orthopaedic Department Ny kobing F Hospital Surgical Department Orthopaedic Hospital Arhus.

Table 4 Pre operative period of observation of pseudarthrosis involving the malleoli

	Pre operative period of observation In months				
	6–8	9–17	18–24	> 24	Total
Medial malleolus	7	18	0	8	33
Lateral malleolus	2	2	1	1	6
Total	9	20	1	9	39

ankle when the patient was walking In five cases operations were indicated because a post traumatic dislocation of the ankle joint had to be corrected it was in particular a reposition of the dislocated malleolar fragment that was required

Operations on the Medial Malleolus

In 32 cases the ankles were exposed to surgical treatment on account of pseudarthrosis involving the medial malleolus Operation had to be repeated in one case and a total of 33 operations were thus performed (Table 4)

Among the 33 operations on the medial malleolus were five which included extirpation of the malleolar fragment and osseous union of the pseudarthrosis was attempted in the remaining 28 cases

The primary results to be obtained by the various types of operation included in the latter category appear from Table 5 It emerges from this table that osseous union was obtained only in 18 cases out of 28 Still in four of these cases osseous union did not occur until more than four months after operation (in one case five months after and in the remaining more than one year after operation) thus in these four cases union can hardly have been a direct result of the operation

In fact the desired result was obtained only in 14 cases out of the 28 exposed to surgery (50 per cent)

The relative effect to be obtained by the individual types of operation can hardly be reliably evaluated because of the small number of cases Results seemed to be optimal however if operation included excision of the fibrous tissue restoration of fracture surfaces fixation of the malleolar fragment and application of bone grafts using these procedures healing was achieved in five cases out of six In one case

Table 5 Incidence of union after the various surgical measures used in the treatment of pseudarthrosis involving the medial malleolus

Type of operation	No of cases	Duration of healing process < 4 months	Duration of healing process > 4 months	No of cases in which union failed
Excision of fibrous tissue restoration of fracture surfaces, fixation of malleolar fragment	7	4	0	3
Same as above associated with application of autologous bone graft	6	5	0	1
Fibrous tissue not excised fixation of malleolar fragment exclusively	3	0	1	2
Fibrous tissue not excised application of autologous inlay graft	4	2	2	0
Application of heterologous bone graft (Kieler bone)	2	0	1	1
Drilling of the pseudarthrosis	6	3	0	3
Total	28	14	4	10

in which this procedure failed to bring about healing bone chips had been applied in the defect at the pseudarthrosis and the malleolar fragment had been fixed by a peg This fixation may have been in sufficient because osseous union had not yet occurred 11 months after the operation

In cases in which the pseudarthrosis had not been excised and nothing except inlay grafts or bone pegs had been applied healing immediately after operation was seen only in two cases out of four (Figure 1) in one case healing occurred five months after operation in the other healing was not achieved until more than one year later

Results would be particularly poor if bone grafts were not applied (Figure 2) and also when bone grafts of heterologous type were used results would be equally poor if drilling according to Beck s method was used (Figure 3) Among 18 cases exposed to the above measures healing within four months after operation was seen only in seven

Table 6 Roentgenological findings in 28 cases of surgically treated medial malleoli with fibrous union

Roentgenological findings	Degree of Arthrosis			
	Absent	Mild	Marked	Total
Satisfactory	14	3	1	18
Less satisfactory	0	2	0	2
Poor	0	3	5	8
Total	14	8	6	28

The following criteria were used as a basis for the tabulated *classification of the roentgenologically results*

Satisfactory No visible dislocation

Less satisfactory Backward or forward displacement of the medial malleolus not exceeding 2 mm Dorsal and/or backward displacement not exceeding 2 mm of posterior tibial fragment Normal position of talus and absence of other dislocations of the ankle joint

Poor Displacements more marked than those mentioned above

The following criteria were used as basis for the tabulated *classification of arthrosis*

Absence of arthrosis normal joint space, absence of marginal osteophytes

Mild arthrosis Slightly reduced joint space and/or moderate but distinct formation of marginal osteophytes

Marked arthrosis Changes more severe than those mentioned above (reduction of the joint space will often be more marked and formation of marginal osteophytes more intense, subchondral sclerosing may be manifest and the joint may occasionally be deformed)

It appears from the table that the incidence of arthrosis would be low if the ankle joint were not dislocated (according to the roentgenological picture satisfactory result) This is consistent with the fact that dislocation of the joint rather than malleolar pseudarthrosis predisposes to arthrosis of the talocrural articulation (Sneppen 1969)

Table 7 illustrates the clinical findings at follow ups of patients in whom the pseudarthrosis had healed up patients in whom the pseudarthrosis persisted and patients in whom the malleolar fragment had been excised

The following criteria were used as a basis for the tabulated *classification of the clinical findings*

Table 7 Clinical findings at follow ups of 28 patients with surgically treated pseudarthrosis involving the medial malleolus

Status of medial malleolus	No of cases	Subjective result			Objective result		
		Fair	Medium	Poor	Fair	Medium	Poor
Absence of pseudarthrosis	17	7	2	8	6	4	7
Presence of pseudarthrosis	8	3	3	2	5	1	2
Malleolar fragment excised	3	3	0	0	2	0	1
Total	28	13	5	10	13	5	10

Subjectively satisfactory No complaints or only mild complaints to be provoked by excessive strain
Subjectively less satisfactory Complaints of more severe character to be provoked by excessive strain and/or regular complaints although not of a severity to interfere with the patient s normal activity
Subjectively poor Complaints of more severe character
Objectively satisfactory Essentially normal conditions
Objectively less satisfactory Mobility in at least one of the other joints of foot or ankle in reduced to about 1/3 or 2/3 of normal and/or muscular atrophy (about 1 cm) on crus or femur Neither the foot nor the ankle are deformed Normal gait
Objectively poor Mobility reduced to a higher degree and/or more severe degree of muscular atrophy deformity of foot or ankle may be in evidence and the gait may be abnormal

It appears from the table that findings in these three groups of patients did not differ whether considered from a subjective or an objective point of view

This is consistent with the fact that the presence of malleolar pseudarthrosis together with the results obtainable by operation of such pseudarthrosis does not influence the long term prognosis in cases of fracture of the ankle (Sneppen 1969)

Operations on the Lateral Malleolus

In cases of pseudarthrosis involving the lateral malleolus surgical measures were instituted only on six occasions



Figure 4 Surgical treatment of pseudarthrosis involving the lateral malleolus application of sliding graft the pseudarthrosis was not excised The photo to the left was taken shortly after operation the one to the right was taken a few years later

Ages of patients at the time of accident varied from 10 to 62 years averaging 45 years Follow up periods prior to operation covered from six months up to five years averaging two years and four months (Table 4)

The following types of operations were performed the pseudarthrosis was excised and the malleolar fragment fixed in two cases a sliding graft was applied in one of these cases Osseous union occurred within about three months in both cases In two cases the fibrous tissue was not excised but autologous inlay grafts exclusively were applied over the pseudarthrosis defect (Figure 4) In one of these cases healing occurred within three months in the other within about one year In one case drilling of the pseudarthrosis resulted in healing within about four months In one case a small malleolar fragment was excised

Thus the results obtained by surgery were satisfactory in all cases but one in which inlay graft exclusively had been applied and the pseudarthrosis had not been excised healing in the latter case was not achieved until one year later

Follow up

The six patients who had been exposed to surgery on account of pseudarthrosis involving the lateral malleolus were all examined at follow ups

Periods of observation were calculated from the time of operation to the time of follow ups and covered from one to 17 years averaging eight years and eight months

According to the roentgenological findings at follow ups results were found to be satisfactory in four cases and poor in two In the latter two patients the arthrosis was marked Among patients in whom results were found to be satisfactory one had a mild degree of arthrosis and one had marked arthrosis

Considered from a clinical point of view the subjective results were satisfactory in three cases and poor in another three likewise the objective results were satisfactory in three cases and poor in three

DISCUSSION

Indications for surgical intervention Whenever it is to be decided whether or not operation is indicated it must be taken into considera tion that symptoms of pseudarthrosis involving the malleolus are not characteristic consequently it may be difficult to determine definitely in the individual cases whether such symptoms actually are due to the pseudarthrosis or to other sequelae of the fracture For that reason exclusively it may be open to doubt whether the symptomatology is influenced at all by such surgical treatment of the pseudarthrosis

Furthermore it must be taken into consideration that osseous consolidation of the pseudarthrosis does not contribute to a long term relief of the patient s complaints bearing in mind that the long term prognosis of fractures of the ankle is not influenced by a malleolar pseudarthrosis (Sneppen 1969 1971)

It will be observed that indications for a surgical treatment of malleolar pseudarthrosis rest on a rather frail foundation conse quently rather than using surgical methods or techniques by which osseous union may be achieved only in about 50 per cent of the cases it might be more advisable to abstain from operation in the case of malleolar pseudarthrosis

On the assumption that a sufficiently effective surgical method is available namely a method by which osseous healing might be ob tainable in almost all cases such a method is not indicated except in the very few cases in which the following requirements are fulfilled

1 Other serious sequelae of the fracture must not be demonstrable by roentgen examination
2 Operation must be performed at an early stage preferably within

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Institute of Medical Sciences Banaras Hindu University Varanasi, India

SKELETAL DEFECTS INDUCED BY CYCLOPHOSPHAMIDE (ENDOXAN ASTA) IN CHICK EMBRYOS—PRELIMINARY REPORT

Department of Anatomy

SHAMER SINGH S M TULI & P K GUPTA

Cyclophosphamide a potent antitumour agent recently [illegible] and put to clinical use since 1958 belongs to the alkylating [illegible] drugs used in cancer chemotherapy It is not active *in* [illegible] and is believed to be transformed to an alkylating agent [illegible] 1967) It has proved to be teratogenic to various labora[illegible] e g rat (Wilson 1964 Kreybig 1965 Kreybig & Schmid[illegible] et al 1967 Singh 1970) rabbit (Gerlinger 1964) and [illegible] Ohzu 1965 Gibson & Becker 1968) Chick embryos [illegible] be subjected to the teratological effects of cyclophospha[illegible] et al 1963) when this drug was injected into the albu[illegible] eggs prior to their incubation There appears to b[illegible] report on the teratogenic effect of cyclophosphamid[illegible] This is a preliminary report describing the effects of [illegible] when injected into the yolk sac during 1–6 day[illegible] period

MATERIALS AND METHO[illegible]

Fertile eggs of the white leghorn chicken were obtained fr[illegible] farm Fresh solution of the cyclophosphamide was prep[illegible] time prior to injection and within 2 hours the inj[illegible] yolk sac of the eggs by the technique described earlier [illegible] the experimental eggs received 0 04 cc of the solution [illegible] of the drug the control eggs received the same qu[illegible] of the control eggs were also incubated without [illegible] cyclophosphamide (0 005 mg 0 01 mg and 0 02 mg [illegible] during incubation along with corresponding controls [illegible]

Table 1 Lethal and teratogenic effect of cyclophosphamide in chick embry

		Controls			
1	Day of treatment	4th		5th	
2	Amount of norm saline in c cs	–	0 04	–	0 04
3	Quantity of the drug in mgs	–	–	–	–
4	No of eggs used	20	25	25	25
5	No of deaths	*1 (5%)*	*3 (12%)*	*1 (4%)*	*3 (10%)*
		8 8%		12 %	
6	No of abnormals	–	–	–	–

Significant when compared with control on 5th day $P < 0.01$
Significant when compared with control on 4th day $P < 0.01$
Significant when compared with same dose on 4th day $P < 0.02$
Significant when compared with *same dose on 4th day* $P < 0.001$
** Significant when compared with 0 05 mg on 4th day $P < 0.001$
Not significant when compared with same dose on 4th day $P > 0.05$

4–5 were found to be more susceptible with the higher dosage Further injections in the experimental eggs were made on the 4th and 5th day of incubation with 0 035 mg to 0 08 mg of the drug in 500 eggs (Table 1) Control eggs were run with each experimental group All eggs were opened on the 19th or 20th day of incubation and the chicks were killed by drowning in a tray of water Gross malformations were carefully observed and recorded and the specimens were weighed before preserving them in the fixatives.

OBSERVATIONS

In the first series of experiments (doses 0 005–0 02 mg) stunting of growth was more marked on the first three days of incubation especially with the higher doses However moderate stunting was always noted in all cases when the drug was injected during the 5th day of incubation even in the smallest doses Ectopia viscerum and exophthalmos were found in a chick which received 0 002 mg of the drug on the 4th day of incubation An interesting case of a chick with three beaks and three eyes was obtained with an injection of 0 005 mg of the drug injected on the 4th day the case has been reported (Tuli & Singh 1970) This seemed to be an accidental finding because this anomaly could not be reproduced when the same dose on the same day was repeated in another 150 eggs

When higher doses of cyclophosphamide (0 035 to 0 08) were injected on the 4th and 5th day of incubation the maximum number of

n injected into the yolk sac on the 4th and 5th day of incubation

			Experimental			
	4th				5th	
04	0 04	0 04	0 04	0 04	0 04	0 04
035	0 04	0 05	0 035	0 04	0 05	0 08
	130	30	30	120	50	50
(36 4%)	*31 (23.8%)*	*12 (40%)*	*3 (10 %)*	*31 (25 8%)*	*9 (18%)*	*39 (78 %)*
	30 4%				32 8%	
(4 4%)	7 (5 3%)	– (0%)	5 (16 6%)	28 (23 3%)**	21 (42%)	1 (2%)

malformed embryos were observed in the latter group (Table 1) The higher dose of 0 05 mg on the 4th day of incubation was rather more lethal (40 per cent) than teratogenic (0 per cent) However the same dose was found to be most teratogenic when given on the 5th day of incubation and produced malformation in the 21 surviving chick embryos out of the 50 eggs injected i e 42 per cent (Figure 1) When the dose was increased to 0 08 mg it proved to be most lethal for the 5 day old embryo resulting in 39 immediate deaths out of 50 eggs injected (78 per cent) Malformations produced by cyclophospha mide injections (Figures 2 and 3) included defects in the eyes (e g exophthalmos bleb formation over the eyes and absence of eye lids) beak defects especially of the lower beak (shortening of the beaks crossing of the beaks parrot beak) limb deformities (shortening curving and dislocation) toe defects (varying degrees of ectrodactylae bending and misdirection) exencephaly due to crania bifida ectopia viscerum and stunting of growth (Table 2) The number of anomalies per malformed embryo was observed to be more in the group treated on the 4th day than in the one treated on the 5th day i e 3/chick vs 2 1/chick (Tables 1 and 2) Stunting was most marked with 0 05 mg doses injected on the 5th day of incubation resulting in an average wet weight of 15 g (average wet weight in controls was 25 g) Ectopia viscerum was the commonest malformation observed with practically all doses In a severe type it presented liver and heart also Some

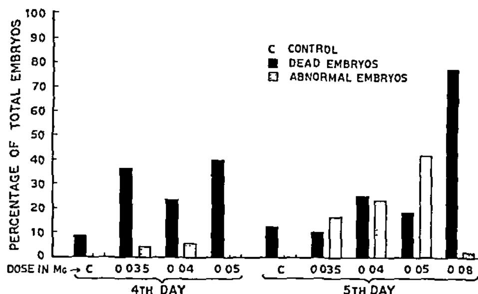


Figure 1 Lethality and teratogenicity induced by cyclophosphamide in chick embryos

Table 2 Frequency of malformations observed during 19-20 days in chick embryos after cyclophosphamide injection into the yolk sac on the 4th and 5th days of incubation

Day	4th day			5th day			
Doses	0 035 mg	0 04 mg	0 05 mg	0 035 mg	0 04 mg	0 05 mg	0 08 mg
rmations							
ye	1	2	–	–	5	3	–
eak	1	3	–	–	6	9	
Limbs	1	1	–	–	5	–	–
4 Toes	2	5	–	–	6	7	–
5 Exencephaly	1	2	–	–	4	2	–
6 Ectopia viscerum	3	7	–	3	12	8	1
7 Stunting (moderate)	2	1	–	5	17	8	–
8 Stunting (severe)	–	2	–	–	14	16	–
	11	23	–	8	69	53	1
Average wet weight in (Normal = 25 g)	23 3	21 3	–	24	18	15	–

N B Multiple anomalies of the individual chicks have been counted separately

Figure 2 Normal chick embryo 20 days old (control)



defects e g scoliosis meningocele swelling in the neck region and rudimentary wings were scattered in their occurrence

DISCUSSION

This preliminary study has demonstrated that the cyclophosphamide when injected in the yolk sac of developing chick embryos produces deformities of the limbs beak skull spine and eyes besides causing ectopia viscerum and stunting of growth in most of the cases Some of the malformations e g of the beak limbs eyes and inhibition of growth have been described by Gerlinger et al (1963) in their report where this drug was injected into the albumen of the chick eggs prior to incubation However the ectopia viscerum frequently observed with every dose of cyclophosphamide in the present experiments has not been mentioned by them The exencephaly and meningocele have not been found either in their experiments whereas the reduction in the tail described by them has not been seen in the present cases These differences can be due to different times of injections (prior to incubation or during incubation) or due to the injection of the drug into different media (albumen or the yolk sac) All major organogenesis in the chick has begun by 48 hours of incubation and as the chick embryo develops in a cleidoic system any drug or dye injected before or during the first few hours of incubation will be present when the



Figure 3 All embryos 20 days old

A Embryo showing parrot beak deformity absence of eyelids and ectrodactylae induced by 0 04 mg of cyclophosphamide injected into the yolk sac on 5th day of incubation

B Embryo showing micrognathia of lower beak rotation of right limb and ectrodactylae induced by 0 04 mg of the drug on 5th day

C Embryo showing advanced deformity of the limbs with a single toe in each rudimentary wings shortened lower beak absent eyelids marked ectopia viscerum showing liver and part of the heart and severe stunting of growth caused by 0 04 mg of cyclophosphamide injected into the yolk sac on 5th day of incubation

D Embryo showing multiple anomalies e g rudimentary wings short limbs with ectrodactylae meningocele shortened lower beak bleb over the eyes and ectopia viscerum and severe stunting of growth caused by 0 04 mg of cyclophosphamide injected in the yolk sac on 5th day of incubation

embryo passes through later susceptible periods The amount of the cyclophosphamide injected by Gerlinger et al (1963) prior to incubation has been much more (0 1 mg) than that used by us during the 4th and 5th day of incubation (0 035 mg-0 08 mg) and it was probably available in a fair amount during a later period to cause some of the similar anomalies in their cases or it has affected the primordium of these organs earlier at the stage of chemodifferentiation The yellow yolk is about 8 times as viscous as the white and the difference in viscosity of the media may account for the different rate of diffusion or migration of the drug to reach the developing embryo Schlesinger (1958) stated that the migration of substances through the yolk depended upon the relative density of the yolk and that of the sub-

stance injected Beaudoin (1961) found that the higher lethal and teratogenic effect of saline in one of his two groups of control eggs was due to mechanical factors involved in the technique of injection i e in the white or the yellow yolk These differences in malformations may also be due to other factors since the lethal and teratogenic effects induced by cyclophosphamide in rat foetuses by different workers have also shown variations Although Kreybig (1965) did not find any effect of the cyclophosphamide when injected into pregnant rats on the 11th day of gestation Chaube et al (1967) found that the same drug given on the 11th day of gestation produced brain and facial malformations in the litters However in experiments conducted by Singh (1970) cyclophosphamide caused resorption of all the embryos when injected in the mother rat on the 11th day of gestation

Although the results of teratogenicity depend not only on the species but even on the strains of experimental animals (Cahen 1964) the malformations produced by cyclophosphamide in the chick and rat embryos have shown striking similarities Anomalies of the head region e g exencephaly brachygnathia meningocele and opened eyes reported in rats and mice by different workers have been seen in the chick embryos in the present preliminary study Even the ram s head i e thickening of the neck region described in rat foetuses (Kreybig & Schmidt 1967 Singh 1970) has also been found in these chick embryos Limb deformities and anomalies of the toes induced by cyclophosphamide in rats (Chaube et al 1967) and in mice (Gibson & Becker 1968) have also been produced in the chick embryos in the present investigation The ectopia viscerum commonly observed in the chick embryos in this study has not been reported to be caused by cyclophosphamide in the rat mice or chick embryos These malformations are however known to be produced in chick embryos by other teratogenic agents as well It is now established that apparently similar defects may be produced by agents of dissimilar nature (Landauer 1953 Duraiswami 1955) These substances may have acted at different times on the same series of developmental events or entirely different events all of which were necessary for the natural development of an organ any part of the embryo or the embryos as a whole It seems obvious that such diverse substances which act as teratogenic agents must work primarily by interfering with some normal biochemical or metabolic activities of the developing embryonic cells and tissues thus resulting in the abnormal development Teratogenic specificity of any agent is reflected by the production of a syndrome of malforma

tions characteristic of the particular agent the nature of malformations being determined by the pathways of the action of the agent and how that relates to developmental events at the time of the treatment and afterwards

Smaller doses of 0 035 mg have produced anomalies in 4 4 per cent of embryos when injected on the 4th day of incubation, as compared with 16 6 per cent produced by injection of the same dose on the 5th day (Table 2) the difference however is not statistically significant ($P < 0\ 1$) With doses of 0 04 mg the embryos affected on the 4th day were 7 out of the 130 eggs injected i e 5 3 per cent as compared with the 23 3 per cent embryos affected on the 5th day by the same dose the difference being highly significant ($P < 0\ 001$) Similarly the number of embryos affected by a 0 05 mg dose on the 5th day is much more (42 per cent), whereas none survived as a malformed embryo with the same dose injected on the 4th day ($P < 0\ 001$) The doses of 0 04 mg and 0 05 mg have thus proved most teratogenic in affecting the chick embryos on the 5th day of incubation (Figure 1) Although the embryos affected by the treatment on the 4th day have been *significantly fewer as compared with the 5th day group more* embryos of the former group have shown multiple anomalies e g 11 malformed embryos in the 4th day group have exhibited 34 anomalies (Tables 1 and 2) i e 3 per embryo as compared with the 5th day group (131/55 = 2 4 per embryo)

Lethal effects of the cyclophosphamide (Table 1) in the two experimental groups have not been much different i e 30 4 per cent in the 4th day group and 32 8 per cent in the 5th day group ($P > 0\ 05$) although mortality with similar doses on the 5th day has been less (Figure 1) However the mortality in each experimental group as compared with the corresponding control group has been significantly more ($P < 0\ 01$) The mortality rate in the control eggs themselves has been far greater in the group where normal saline was injected than in the noninjected eggs

The mechanism by which cyclophosphamide produces these varied malformations cannot be adduced from the present findings However damage to the mesenchymal tissue is obvious As the drug is inactive *in vitro* and becomes active only in the tissues of the host *(mother/foetus)* the *transformation* of the cyclophosphamide to an active alkylating agent in the chick embryo is positively occurring in the tissues of the embryo itself

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Department of Orthopaedics Ohmi a Red Cross Hospital
Kamiochiai 903 Yono-shi Saitama Ken Japan

PYCNODYSOSTOSIS

(dysostosis petrosans)

SATORU SHIRAISHI

Accepted 3 x 71

...cnodysostosis is a term coined by Maroteaux in 1962 to describe ...disorder characterized by open cranial suture generalized bone ...rosis and fragility shortening of the terminal phalanges etc This ...se complex was reported as an atypical case of dysostosis cleido-...alis or osteopetrosis until 1954 when this entity was first dif...iated from these two diseases by Aoike and named dysostosis ...ns

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68 year old male

...of his five brothers had a prominent sagittal groove in the ...e daughters were small and had similar shaped heads and ...r entgenogram of the pelvis of his first daughter taken ...evealed segmentation of the fourth and the fifth ...the major fontanelle of the baby was noted by ...m...t to persuade his family to come to the X ray

...ut his birth history He had fractured his right ...and his right fifth metatarsal three years ago ...earing for ten years He gradually lost his teeth

...was 148 centimeters tall The shoulders were ...was enlarged with frontal bossing (Figure 1) The

...Matsunaga M and Ichikawa ... at the Eleventh ...in

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Department of Orthopaedics Ohmiya Red Cross Hospital
Kamiochiai 903 Yono-shi Saitama ken Japan

PYCNODYSOSTOSIS

(dysostosis petrosans)

SATORU SHIRAISHI

Accepted 3 v 71

Pycnodysostosis is a term coined by Maroteaux in 1962 to describe a disorder characterized by open cranial suture generalized bone sclerosis and fragility shortening of the terminal phalanges etc This disease complex was reported as an atypical case of dysostosis cleidocranialis or osteopetrosis until 1954 when this entity was first differentiated from these two diseases by Aoike and named dysostosis petrosans

The purpose of the writer is to report two cases of pycnodysostosis (68 year old male and 19 year old female) and review forty eight cases from foreign and Japanese literature These meet the criteria for pycnodysostosis although the diagnosis and the title of the reports varied according to the authors

Case 1

This patient was a 68 year-old male

Family history Two of his five brothers had a prominent sagittal groove in the forehead. All of his three daughters were small and had similar shaped heads and short stubby fingers The roentgenogram of the pelvis of his first daughter taken before the cesarean section revealed segmentation of the fourth and the fifth lumbar spinous processes The large major fontanelle of the baby was noted by a pediatrician A repeated attempt to persuade his family to come to the X ray department failed

History Nothing is known about his birth history He had fractured his right elbow at the age of twenty five and his right fifth metatarsal three years ago He had progressive difficult in hearing for ten years He gradually lost his teeth after the age of fifty

Clinical findings The patient was 148 centimeters tall The shoulders were narrow and drooping The skull was enlarged with frontal bossing (Figure 1) The

Case 2 was presented orally by Matsunaga M and Ichikawa M at the Eleventh East Japan Orthopaedic Meeting in 1962



Figure 1 Case 1 The head was enlarged with frontal bossing The base of the nose was depressed and the distance between the eyes was unusually widened The shoulders were narrow and drooping

biparietal diameter was increased The base of the nose was depressed and the distance between the eyes was unusually widened There were no teeth and a high arched palate was seen There was no serious disproportion between the trunk and extremities except for the hands and feet The lateral two thirds of the right clavicle was replaced by a fibrous cord Both shoulders could be easily approximated His fingers and toe were short and stubby

Roentgenographic findings The skull was broad with a cephalic index of eighty two The cranial sutures were separated (Figure 2) There was wormian bone formation along lambdoidal suture Sclerosis involved the base of the skull The pituitary fossa was small and deep The tip of the clinoid process was curved forwards and thickened The nasal bone and the paranasal sinus were hypoplastic The flat angle of the mandible was the outstanding feature There were no teeth

The lateral two thirds of the right clavicle was completely absent and the remaining part was hypoplastic (Figure 3) Slight hypoplasia of the acromial end of the left clavicle was present The residual acromion growth plate was seen on the left side

A varus deformity of the right elbow was noted along with left radius ver growth The metaphyseal part of the metacarpals and the proximal phalanges were abnormally broad The middle phalanges were short and wide The terminal phalanges were short and tapered (Figure 4)

The superior and inferior end plates of the vertebrae were sclerotic and irregular



Figures 2 A and 2 B Anteroposterior and lateral roentgenograms of the skull Case 1 The skull was broad with a cephalic index of eighty two The cranial sutures were separated There was wormian bone formation along lambdoidal suture Sclerosis involved the base of the skull and the mandible The paranasal sinus was hypoplastic The flat angle of the mandible was noted No teeth were seen

The pelvis showed generalized increased density and the iliac components were small (Figure 5)

Coxa valga was noted and the distal femoral metaphysis was broad bilaterally Lateral ligamentous instability to thirty degrees was present in the left knee The first metatarsal neck and diaphysis were broad The phalanges were broad and short. A healed fracture was seen in the middle of the fifth metatarsal where the diaphysis was thickened (Figure 6)

Laboratory results were within normal limits

Biopsy The remaining portion of the right clavicle was connected to the acromion with a fibrous cord The tip of this part was taken as a specimen The other specimen was taken from the left ilium. Histologically normal lamellar bone hematopoietic marrow and fatty marrow were seen. The bone marrow was partially fibrous The trabeculae were rather thick A prominent cement line was noted on the border between the clavicle and the thick fibrous tissue

Case 2

The patient was a nineteen year old girl

Family history Her parents were cousins There was no history of a patient s disorder among her relatives.



Figure 5 Roentgenogram of pelvis Case 1 Generalized increased density was seen and the iliac components were small A defect in left ilium shows the area of biopsy

sclerosis and fragility Since then similar cases had been reported by Shima (1949) Seigman (1950) Ito (1952) and Hasue (1954) although their terminology of the diagnosis varied In 1954 (in Japanese) and in 1958 (in English) Aoike reviewed these cases and separated a new hereditary bone disease characterized by the following features (1) heredity (2) cranial malformation similar to that of dysostosis cleidocranialis (3) dwarfism (4) maldevelopment of pelvis (5) sclerosis of endplate of vertebral body (6) broad metaphysis (7) dysplasia of distal phalanges (8) bone fragility (9) bone sclerosis (10) histological feature similar to that of osteopetrosis

In 1962 Marouteaux reported two similar cases which he labeled pycnodysostosis The characteristic features of pycnodysostosis are (1) heredity (2) open cranial suture and fontanelle (3) hypoplastic mandible (4) frontal and parietal bossing (5) dwarfism (6) hypoplasia of terminal phalanges (7) bone fragility (8) bone density The

Figure 6 Roentgenogram of the right foot Case 1 The phalanges were broad and short A healed fracture was seen in the middle of the fifth metatarsal where the diaphysis was thickened The first metatarsal neck and diaphysis were broad





Figure 7 Case 9 The hard palate was steep A double row of teeth was seen

author believes that dysostosis petrosans by Aoike (1954) and pycnodysostosis by Maroteaux (1962) are apparently the same entity

Forty six cases with open cranial sutures and bone sclerosis were found in the foreign and Japanese literatures (Table 1) The author studied the characteristics common to these forty six cases and in



A B

Figures 8 A and 8 B Anteroposterior and lateral roentgenograms of skull Case 9 The coronal and sagittal diameters of the skull were both fifteen centimeters There was wide separation of the coronal sagittal and lambdoidal sutures The mandibular angle was flattened to almost 180 degrees There was mild platybasia

cluded the two cases discussed There were twenty males and twenty eight females As to age distribution there were eleven cases under the age of ten fifteen cases between eleven and twenty fourteen between twenty one and thirty four between thirty one and forty and four over forty one years of age Twenty of forty eight cases occurred in brothers and sisters three were cousins (two of them were a brother and his sister) and two were an uncle and his nephew

The characteristics of these forty eight cases were (1) All patients had a short stature (2) The cranial sutures were open in all cases (3) A loss of mandibular angle was seen in thirty-one cases (4) A defect of the clavicle was found in three cases This association has not been reported previously (5) The fingers and the toes were short in forty six cases and in thirty eight shortening of the distal phalanx was described (6) An abnormal alignment of teeth was described in fifteen cases (7) All cases showed some degree of osteosclerosis (8)



Figure 9 Lateral roentgenogram of spine Case 2 The superior and inferior portions of the vertebral bodies were sclerotic and an anterior notch of each body was found

A history of repeated fractures was reported in forty three cases In the usual case a transverse fracture occurs in the midshaft and after healing cortical thickness remains resulting in a spindle shaped broadening (9) Broadening of the metaphysis of the tubular bones was found in nine cases (10) Histological examination was performed in several cases and in four of them the findings were similar to those found in osteopetrosis (11) The laboratory examination usually showed no abnormality No hepatosplenomegaly was reported

As mentioned above this is a disease complex which combines features of cleidocranial dysostosis and osteopetrosis in various degrees clinically roentgenographically and histologically

Soeda (1963) reported a quite interesting case study of a girl whose sister seems to fit the typical case of osteopetrosis These two diseases have some common features such as generalized osteosclerosis bone fragility and broadening of the metaphysis Fractures usually occur in the diaphysis and a spindle shaped broadening persists in that area

Table 1 48 cases with open crani

Reported by	Age (Years)	Sex	Dwarfism	Open cranial suture	Obtuse mandibular angle	Defect of clavicle
Aoike	30	♀	+	+		±
Shima	17	♂	+	+		±
Shima	20	♀	+	+		—
Seigman	21	♀	+	+	+	—
Ito	18	♂	+	+		—
Ito	16	♂	+	+		—
Ito	13	♂	+	+		—
Ito	10	♂	+	+		—
Thomsen	21	♀	+	+	+	±
Thomsen	40	♂	+	+	+	±
Hasue	30	♂	+	+		—
Hasue	20	♀	+	+		—
Abboud	8	♀	+	+	+	
Abboud	5	♂	+	+		
Giaccai	28	♂	+	+		±
Sarrouy	12	♂	+	+		
Sarrouy	3	♀	+	+	+	
Thoms	28	♀	+	+	+	±
Thoms	9 mo	♀	+	+	+	±
Palmer	20	♂	+	+	+	
Palmer	20	♂	+	+	+	
Palmer	8	♀	+	+	+	
Palmer	16	♂	+	+	+	
Palmer	13	♂	+	+	+	
Marouteaux	4	♂	+	+	+	—
Marouteaux	1.5	♀	+	+	+	—
Kalliala	26	♀	+	+		±
Andren	21	♀	+	+		—
Andren	21	♀	+	+		±
Shuler	7	♂	+	+	+	±
Shuler	43	♂	+	+	+	±
Soeda	38	♀	+	+	—	+
Sugiura	17	♀	−	+	+	
Sugiura	53	♀	+	+	+	
Elmore	16	♀	+	+	+	±
Dusenberry	22	♀	+	+	+	
Dusenberry	28	♀	+	+	+	—
Dusenberry	38	♀	+	+	+	—
Koh	6	♂	+	+	+	
Koh	10	♀	+	+	+	
Koh	17	♀	+	+		±
Koh	53	♀	+	+	−	

ures and bone sclerosis

Short halanges	Changes of teeth	Widening of metaphysis	Bone sclerosis	Experience of fracture	Family relation
+	+	+	+	+	
+			+	+	Brother
+	—	+	+	+	Sister
+			+	+	
+	+		+	+	Brother
+	+		+	+	Brother
+	+		+	+	Brother
+	+		+	+	Brother
+		+	+	+	
+			+	+	
+			+	+	Brother
			+	+	Sister
-		+	+	+	Sister
+			+	+	Brother
+	+		+	+	
—		+	+	+	Brother
			+	-	Sister
+			+	+	
+			+	+	
+		+	+	+	
+			+	+	
+			+	+	
+			+	+	
+			+		
+			+	+	[illegible]
+			+	-	[illegible]
+	+		+	+	
+	-	+	+	+	[illegible]
+	-	+	+	+	[illegible]
+			+	+	[illegible]
+			+	+	[illegible]
+	—		+	+	
+			+	+	
+			+	+	
+	+		+	+	
+	+		+	+	
+	+		+	+	
+	+		+	+	
+			+		
+			+	+	
+			+	+	
+			+	+	

Table

Reported by	Age (Years)	Sex	Dwarfism	Open cranial suture	Obtuse mandibular angle	Defect of clavicle
Itohara	21	♀	+	+	+	−
Itohara	29	♀	+	+	+	−
Itohara	37	♂	+	+	+	−
han	30	♀	+	+	+	−
Shiraishi	68	♂	+	+	+	+
Shiraishi	19	♀	+	+	+	±

\+ present
− absent
Defect of clavicle (±) means hypoplasia

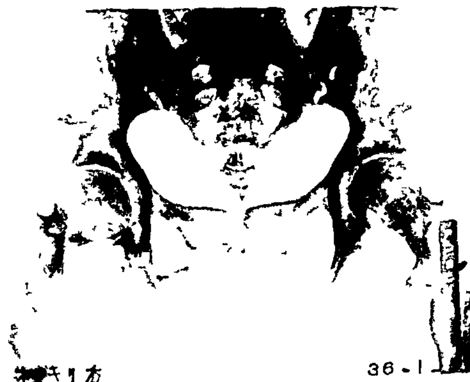


Figure 10 Roentgenogram of pelvis Case 2 The iliac bones were deformed There were old subtrochanteric fractures in both femora Generalized sclerosis of bone was noted

Cont.)

Short phalanges	Changes of teeth	Widening of metaphysis	Bone sclerosis	Experience of fracture	Family relation
+	+		+	+	Cousin
+	+		+	—	Brother Cousin
+	+		+	+	Brother Cousin
+			+	+	
+		+	+	+	
+	+	—	+	+	

presumably due to lack of remodeling ability Common findings were also noted histologically The relationship between the pycnodysostosis and the osteopetrosis is suggested to explain the occurrence of the two diseases in sisters

Pycnodysostosis presents a number of changes characteristic of cleidocranial dysostosis such as dwarfism open cranial sutures a flat mandibular angle with dental abnormality In addition a clavicular defect was also noted clearly in three cases and as stated before this has not been described in previous reports Although the developmental anomalies in Case 1 were so marked and typical of the cleidocranial dysostosis there were also shortening of the distal phalanges and osteosclerosis of pelvis spine and cranial base with broadening of the long bone metaphysis The author believes that Case 1 is one closely akin to dysostosis cleidocranialis In the cases reported as dysostosis cleidocranialis by Fujimoto (1943) Soule (1964) and Fujiwara (1964) one of the features was shortening with tapering of the distal phalanges and osteosclerosis was interpreted from their photographs However the limitation of such a decision as to the presence of bone sclerosis is recognized Thus the possibility of cases of pycnodysostosis reported under the diagnosis of cleidocranial dysostosis is presented Histological features of dysostosis cleidocranialis have not been defined and no report of these two diseases occurring in the same family was found Pycnodysostosis and cleidocranial dysostosis have much in common as to clinical and roentgenographic data However we cannot conclude as to the possibility of a relationship between these two diseases

According to Shima (1949) and Miki (1963) pycnodysostosis was considered to be the combination of dysostosis cleidocranialis and

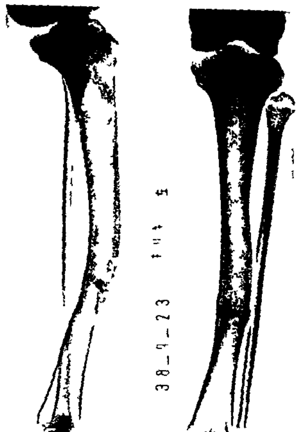


Figure 11 Roentgenogram of the left leg Case 2 A transverse fracture of mid tibia in the healing phase was seen with spindle shaped thickening and anterior bowing



Figure 12 Roentgenogram of hands Case 2 The terminal phalanges were extremely short Cortex of the tubular bones was thick Deformity of the base of the metacarpals was seen

Figure 13 Roentgenogram of feet Case 2 The terminal phalanges were short and flat The metatarsals were also short with broad and deformed bases Cortex of the tubular bones was thick



osteogenesis imperfecta They concluded that the sclerosis was a secondary change from fracture healing The author believes that the bone density is too extensive and diffuse to be considered as bone reaction following a fracture Because of the presence of generalized bone sclerosis the type of fracture and the histological features the disease entity can be considered to be due to the same unknown factor that probably causes osteopetrosis

In conclusion the pathogenesis of pycnodysostosis remains unknown as well as that of cleidocranial dysostosis and osteopetrosis

SUMMARY

Two cases of pycnodysostosis were reported Forty eight cases of open cranial suture and osteosclerosis from foreign and domestic literatures were reviewed

There were twenty males and twenty-eight females Dwarfism open cranial suture shortening of fingers and toes osteosclerosis and bone fragility were noted in almost all cases Flattening of the mandibular angle was found in 65 per cent broadening of the metaphysis in 19 per cent dental abnormality in 31 per cent and clavicular defect in 6 per cent Twenty of forty eight cases occurred in brothers and sisters three were cousins (two of them were a brother and his sister) and two were an uncle and his nephew Histological findings similar to those of osteopetrosis were obtained in four cases

Pycnodysostosis and osteopetrosis have common features clinically



Figure 14 Photomicrograph of bone taken from the ilium Case 2 The thicl trabeculae showed mosaic structure and contained coarse fiber bone and persistent minerali ed osteochondroid fragments (hematoxylin and eosin stain × 60)

roentgenologically and histologic illy There w is one c ise of pycnodysostosis whose sister was presumed to be a case of osteopetrosis Intimate relationship between pycnodysostosis and osteopetrosis is strongly suspected

Pycnodysostosis has a strong resemblance to dysostosis cleidocranialis both clinically and roentgenologically However histological features are not yet clearly described and no report of familial oc currence of pycnodysostosis and cleidocranial dysostosis was found

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Figure 14 Photomicrograph of bone taken from the ilium. Case 2 The thick trabeculae showed mosaic structure and contained coarse fiber bone and persistent mineralized osteochondroid fragments (hematoxylin and eosin stain × 60)

roentgenologically and histologically There was one case of pycnodysostosis whose sister was presumed to be a case of osteopetrosis Intimate relationship between pycnodysostosis and osteopetrosis is strongly suspected

Pycnodysostosis has a strong resemblance to dysostosis cleidocranialis both clinically and roentgenologically However histological features are not yet clearly described and no report of familial occurrence of pycnodysostosis and cleidocranial dysostosis was found

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Department of Orthopaedic Surgery, Sorø, Denmark and
Department of Pathology, Centralsygehuset, Slagelse, Denmark

GANGLION OF THE WRIST—A STRUCTURE DEVELOPED FROM THE JOINT

A Histological Study with Serial Sections

KNUD TOPHØJ & ULRIK HENRIQUES

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McEvedy (1962) described the macroscopic structure of the ganglion. The main structure consists of a cyst with pseudopodia. The main cyst is like a rubber balloon with thin spots in the rubber, and these spots are blown out like pseudopodia. Upon careful examination of the main cyst he found on its deep aspect an attachment to the underlying joint capsule. This attachment is not further described; it can be slender or wide, but there is always a connexion to the joint capsule in the case of ganglia of the wrist. Ganglion of the finger may be connected to the tendon sheath in McEvedy's opinion.

At the connexion with the joint capsule small capsular cysts could be made out in the substance of the joint capsule. If the main cyst is emptied, the gelatinous content of the capsular cysts will empty into the main cyst. McEvedy could find a luminal connexion between all the cysts with a slender probe, but he did not believe that there was a luminal connexion with the joint cavity.

Earlier authors agree with him that there is no direct connexion between the cavity in the ganglion and the joint, in spite of the fact that Eller (1746) described the development of the ganglion as a hernia from the joint. The impression one has from McEvedy's description is that the ganglion is like a tree. The roots are placed in the joint capsule. From these rise a pedicle, short or long, slender or wide, more or less right angled to the main cyst, which is placed subcutaneously, possibly between tendons. The description by Carp & Stout (1928) and De Orsay (1937) can be interpreted in the same way.

We wished to investigate this theory of the ganglion's anatomy

particularly the connexion between the ganglion and the joint The technique used is microscopy of serial sections of ganglia At the same time we tried to inject contrast in the ganglia and to take X rays of them The pictures we obtained were so poorly defined that we found the technique unsuitable

MATERIAL AND METHOD

We studied 18 ganglia of the wrist. The operations were performed under full anaesthesia and with bloodless field All ganglia were extirpated in a tissue block composed of the main cyst pedicle and the connexion between pedicle and joint capsule and here we removed a "foot plate" of joint capsule of about 5 mm in diameter The part of the footplate lined with synovial was marked by sutures All ganglia were prepared for histology in the normal way In addition we made serial sections on six ganglia at right angles to the pedicle from the main cyst and including the footplate The specimen consisted of a piece of tissue 5–7 mm long cut in 10 my thick serial sections

Two of this series were satisfactory i e we had a complete serial section representing all the tissue Three of the series were partly successful, but were not complete because some of the sections could not be interpreted for various technical reasons One of the series failed completely because of shrinkage of nearly all the sections and this was not considered in the material

RESULTS

Histological examination of all serial sections showed the same structure in all the ganglia similar to that described previously (Soren 1966) The ganglion is composed of connective tissue which is not encapsulated from the surrounding tissue though nevertheless there is a difference in consistency of the ganglion and the surrounding tissue which can be seen as a border of the ganglion The part of the ganglion against this border is composed of fibrotic connective tissue whereas the central part is composed of cavities with different appearences (Figures 1 A and 3 A)

Most frequently there is no real endothelial lining to the lumen but there are flattened fibroblasts and single star shaped cells just beside the lumen In some places though the lumen is lined by cells like histiocytes and they can lie in several rows and look like pseudo-endothelium

In addition to the large lumina there are innumerable small lumina which look like capillaries These small lumina are partly in communication with each other and some of them communicate particularly with the big lumina (Figure 2)

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Department II and the Radiology Department Orthopaedic Hospital Copenhagen

FRACTURES AND SUBLUXATIONS OF THE ATLAS AND AXIS

A Follow-up Study of 20 Patients

LISE HENTZER & MARCUS SCHALIMTZEK

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Since Crutchfield in 1933 introduced cranial traction the results of treating fractures of the atlas and axis have changed Prior to that time Osgood & Lund (1928) had reported a mortality of about 50 per cent but during recent years it has declined to less than 10 per cent (Amyes & Anderson 1956 Rogers 1961 Schmidt & Lohr 1969)

In the literature there is a marked difference of opinion as to whether the primary treatment should be conservative or operative Conservative immobilization in fractures of the odontoid process of the axis is preferred by several authors (Amyes & Anderson 1956 Blockey & Purser 1956 Bohler 1965 Hambly 1944 Nachemson 1960) who claim that this treatment results in union of the fracture provided that an early diagnosis is made and provided that reduction and immobilization are sufficient Others (Alexander et al 1958 Cone & Turner 1937 Wilson 1963) have found the risk of re dislocation to be so great that primary operative treatment is invariably indicated

Ramadier & Bombart (1963) found that among 152 fractures of the cervical spine one third affect the uppermost two vertebrae The most common type of atlanto axial fracture is that of the odontoid process (Bohler 1965 Osgood & Lund 1928 Ramadier & Bombart 1963 Wilson 1963) the mechanism of which is hyperflexion or hyper extension of the upper part of the cervical spine Frequently the fracture is accompanied by a forward or backward dislocation of the odontoid process and the atlas Other fractures involving the 1st and 2nd cervical vertebrae are fractures of the atlantal arch of the axial arch and of the axial body

The purpose of the present study was to try to assess the

results of conservative *versus* operative treatment in cases of fractures and/or subluxations of the atlas and axis

MATERIAL

During the period 1960–1968 a total of 29 primarily surviving patients (8 females and 21 males) with traumatic fractures and/or subluxations of the atlas and axis were treated in the Orthopaedic Hospital and in the Neurosurgical Department Bispebjerg Hospital Copenhagen Among these 29 patients 4 had died at follow up and 5 failed to present themselves in spite of repeated requests The material then comprises 20 patients One female and 7 males average age 31 years (range 6–64) had been treated operatively whereas 4 females and 8 males average age 51 years (range 26–80) had had conservative treatment All had a clinical and all but one a radiological follow up examination The follow up period ranged from 1–9 years average 4½ years after the accident The X ray examination included ordinary anteroposterior and lateral views as well as views in extreme flexion and in extreme extension of the cervical spine In addition sagittal and frontal tomography was obtained of all fractures involving the odontoid process

All the patients had primarily had neck pain a fixed posture of the head and restricted mobility of the cervical spine In connection with the trauma one patient developed tetraplegia whereas the others did not exhibit acute neurological signs

In 14 of the 20 cases the fracture was diagnosed on the day of the accident In 2 cases 3 and 5 days later while in 2 cases 4 weeks and in another 2 patients, 4 and 5 months elapsed before the diagnosis was confirmed

*A total of 12 fractures involved the odontoid process One of these was ac*companied by fracture of another cervical vertebra The atlas and odontoid process were dislocated in 6 cases backward in 2 and forward in 4 In 4 cases there was a forward dislocation of the atlas without an associated fracture of the odontoid process One of these patients had an odontoid ossicle one had rheumatoid arthritis and one was a child aged 6 years In the latter patient there was no explanation why the atlas could get subluxated without an associated fracture of the odontoid process

As is apparent from Table 1 all patients with fractures of the odontoid process without displacement had been treated conservatively by immobilization in Camp s collar for 10 to 36 weeks, average 20 weeks One patient aged 80 with chronic bronchitis and respiratory embarrassment was immobilized for only 4 weeks

Surgical treatment had been preferred in 7 of the 10 cases of dislocation of the atlas with or without odontoid fracture Five were primarily treated by fusion One of the remaining 2 did not have *the operation until 5¼ months after* the trauma when he developed signs of cord compression In the other one the fusion was done because of non union of the odontoid process not diagnosed until 5 months after the accident The remaining 3 patients of these groups were treated conservatively In one case this was done because the dislocation of the atlas was so slight that operative fixation was not believed to be indicated In another case there was contra indication in the form of a co existing disease The third patient was treated in a department in which the attitude to these fractures was conservative Two of the patients were treated with Camp s collar for 3 and 6 months

Table 1 Shows the type of fracture and treatment

Type of fracture	No of patients	Treatment	
		Surgical	Conservative
Fracture of the odontoid without displacement	6	0	6
Displacement of the atlas with fracture dislocation of the odontoid	6	4	2
Displacement of the atlas without fracture of the odontoid	4	3	1
Fracture of the arch of atlas without dislocation	1	0	1
Fracture of the arch of axis without dislocation	2	0	2
Fracture of the arch of axis with dislocation	1	1	0
Total	20	8	12

respectively the third one by cranial traction for 3 months followed by Camp s collar for 3 months

All patients with fractures of the atlantal arch or axial arch without displacement (3 in all) were treated conservatively (Camp s collar for 6–12 weeks) The only one of these fractures which was displaced was treated by fusion

Out of the surgically treated patients 5 had had posterior fusion of the 1st and 2nd cervical vertebrae whereas 3 had had posterior fusion of the 1st 2nd and 3rd cervical vertebrae The operation had been performed after the fracture had been reduced by a week or two of cranial traction and the subluxation of the atlas had been reduced Fixation was secured by steel wires around the vertebral arches splitting of the bony surfaces and insertion of bone chips or bone grafts from a bone bank.

RESULTS

Table 2 shows that at follow up 3 patients complained of neck pain However in all cases the pain was intermittent and so mild that analgesics were rarely required

As might be expected the 8 operated patients had a more marked restriction of mobility than the unoperated patients They had mild subjective complaints but all were working in their old jobs Within the group of unoperated patients 5 out of 12 had *restriction of rotation* to less than half the normal However 4 of these patients were over 72 years of age and showed signs of cervical spondylosis deformans Only one patient had signs of cord damage at follow up

Table 2. Symptoms of patients treated surgically or conservatively at time of follow-up

Symptoms	Neck pain	Loss of rotation (more than 50%)	Spinal cord symptoms	Vascular symptoms
Surgical treatment (total 8 patients)	1	8	0	2
Conservative treatment (total 12 patients)	2	5	1	0

This was the patient with rheumatoid arthritis who still had weakness of all limbs and hyperreflexia. However, the pareses were less severe than prior to the treatment. Two of the operated patients complained of dizziness on bending the head backward, one also of associated headache. Possibly, these symptoms were vascular, although the odontoid process and atlas had been accurately reduced and the fusion was firm.

Out of the 20 patients 19 were X-rayed at follow-up. From Table 3 it is apparent that the odontoid fracture had united in 3 of the 4 operated patients. The patient with the ununited odontoid fracture had not had the fusion operation until the non-union had been recognized 5 months after the trauma. Among the conservatively treated patients 7 showed non-union of the odontoid process. Two of them exhibited instability of the atlas on X-rays taken during extreme flexion and extreme extension of the cervical spine. Table 1 shows that yet another patient had an unstable atlas, viz. the conservatively treated patient with rheumatoid arthritis. In this patient the atlas slid 10 mm forward during maximum forward flexion. X-rays of the cervical spine during extreme flexion and extreme extension in the

Table 3. The result of the surgical and conservative treatment of fractures of the odontoid estimated by routine roentgenograms supplemented by tomograms of the odontoid process

Treatment	Healing of the fracture Number of patients	Pseudarthrosis of the odontoid process Number of patients
Surgical (total 4 patients)	3	1 (see text)
Conservative (total 7 patients)	3	4

Table 4 The result of the roentgenograms of patients with fracture dislocation of the odontoid process and atlas or atlas dislocation during extreme flexion and extension

Treatment	Stability of atlas Number of patients	Instability of atlas Number of patients
Surgical (total 7 patients)	7	0
Conservative (total 8 patients)	5	3

surgically treated patients confirmed that the fusion was firm in all cases The uppermost cervical vertebrae moved *en bloc* All the fractures of the atlantal and axial arches had united

Radiography showed incipient development of spondylosis deformans in two out of the 8 operated patients at follow up The spondylosis affected the segments immediately below the fusion In both cases the atlas was displaced 10 mm forward so that the normal lordosis of the cervical spine had been replaced by kyphosis Therefore the development of spondylosis deformans in these two cases must be presumed to have been induced by the altered load on the underlying vertebrae and discs In the remaining 6 operated patients in whom there were no signs of spondylosis deformans the odontoid process and atlas had been reduced to the normal anatomical position

At follow up one of the 12 conservatively treated patients had developed unilateral osteoarthritis of the atlanto axial joint whereas 4 patients exhibited increasing degeneration of the intervertebral discs and spondylosis deformans The apparent higher frequency of spondylosis deformans among the conservatively treated patients must be taken with reservation as the average age of this group was 51 years against 31 years in the operated group (Four of the conservatively treated patients developing spondylosis deformans were all past 70 years of age)

Four patients aged 61–86 years had died at the time of follow up Three had had odontoid fractures with dislocation and one had had a fracture of the axial arch with forward dislocation of the axial body All these patients had been treated by conservative measures The death certificates were inspected It is striking that 2 of the 4 patients had been found dead and that in these 2 cases the actual cause of death was not established The other two had died of bronchopneumonia According to the death certificate one of them had developed quadriplegia after discharge

DISCUSSION

The diagnosis of fracture of the first and second cervical vertebrae may be difficult if the symptoms and signs are slight. However, this possibility should be borne in mind when patients complain of neck pain and restricted rotation in the neck after a head injury. If routine X-rays do not reveal a fracture, they should be supplemented by tomography and oblique views. Fracture and/or subluxation of the atlas had primarily been overlooked for more than four weeks in 4 of the present cases. (X-rays of the cervical spine had not been obtained primarily.)

Manifestations of cord damage were found in 2 patients of the material. These manifestations are reported to be rare in cases of atlantal and axial fractures in which the patient survives. The explanation may be the good spatial conditions in the spinal canal at the level of these vertebrae (Böhler 1965, Schmidt & Lohr 1969) and the fact that if a cord injury occurs in this site the outcome is usually fatal. It is not possible to decide how often death after head injuries is due to overlooked fractures of the first two cervical vertebrae, as there are often other major injuries which are immediately interpreted as the cause of death.

At follow-up non-union of the odontoid process was found in 4 out of 7 conservatively treated patients. In 2 of these 4 cases the non-union was associated with instability of the atlas. None of the patients had symptoms. However, the risk of developing secondary manifestations of cord damage must be considered great in cases where the non-union is associated with radiologically demonstrable instability of the atlas. A patient who had been primarily treated by conservative measures developed signs of cord compression 5½ months after the accident. At this time X-ray examination showed non-union and instability of the atlas. (After a fusion operation the patient was free of symptoms at follow-up.) A patient who had died at the time of follow-up had developed quadriplegia after discharge. This patient also had radiologically demonstrable non-union (but was not subjected to operation because of advanced age). Lastly, it cannot be ruled out that in one or more of the other deceased patients death may have been caused by acute dislocation of the atlas. Several authors have pointed out the same risk of developing secondary myelopathy (Crutchfield 1933, Dunbar & Bronson 1961, Rogers 1961).

All the osteosynthesis fusions healed primarily. After the operation

rotation in the cervical spine was less than half the normal rotation This restriction caused minor complaints but did not interfere with the patients daily activities or work and had not in any case necessitated a change of occupation

Judging by the present material early operative treatment of unstable atlantal and axial fractures is preferable as all the fused cases healed without major sequelae whereas several of the conservatively treated patients have already developed cord symptoms or it is feared that they will do so Moreover the operatively treated patients can be mobilized more quickly and can return to work sooner

SUMMARY

The result of a follow up study of 20 patients with fracture and/or subluxation of the atlas and axis is submitted Twelve patients had been treated by conservative measures and 8 by operation Apart from a clinical examination the follow up included conventional X ray examination supplemented by tomography and by X ray studies during extreme flexion and extreme extension Surgical treatment consisted of posterior fusion of the 1st–2nd or 1st–3rd cervical vertebrae All healed by primary intention and did not give rise to major complaints The postoperative course had always been uncomplicated Out of 8 conservatively treated patients with fractures of the odontoid process of the axis 4 exhibited non union (asymptomatic) One patient who had not undergone operation until 5 months after the injury had cord symptoms which responded to the operation Four of the conservatively treated patients had died at the time of follow up One of them had developed quadriplegia and two had been found dead At the X ray studies done during extreme flexion and extreme extension instability of the atlas was found in 3 out of the 12 conservatively treated patients but in none of the operated ones

It is concluded that early operative treatment of unstable atlantal and axial fractures is preferable to conservative treatment which involves a risk of non union and cord symptoms

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Department of Orthopaedic Surgery O Odense Hospital Denmark

TREATMENT OF CONGENITAL DISLOCATION OF THE HIP IN THE NEWBORN

JØRGEN LAURITZEN

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Ortolani in 1937 was the first to describe how congenital dislocation of the hip (c d h) could be diagnosed immediately after birth Treatment of this condition during the neonatal period described by v Rosen (1957) was short lasting could be carried out on an out patient basis and revolutionized the prognosis Nevertheless far from all patients with c d h receive early treatment even to-day (Tönnis & Kuhlmann 1969)

The present study was designed to investigate for a given period

(1) whether all newborns in a given area (the county of Funen) have been examined for c d h
(2) whether all patients suspected of c d h have been referred to the Department of Orthopaedic Surgery in Odense
(3) whether all cases requiring treatment have been found in the Department and
(4) what the therapeutic results have been

MATERIAL

A *Patients Referred Early*

In 1962 the first newborn infants were referred to the Department of Orthopaedic Surgery Odense because of a suspicion of c d h From Jan 1 1962 to Dec 31 1968 a total of 274 infants were referred within the first 2 weeks of life and another 38 in the age range 2 weeks – 6 months

Out of these 312 infants 54 per cent were referred from the Obstetrical Department of the Odense Hospital 36 per cent from non obstetrical hospital departments or private maternity clinics and 10 per cent from general practitioners after birth at home

The examination was in most cases done in the Orthopaedic Depart

all the hips showed stable reduction The only complication was avascular epiphyseal necrosis in 2 cases treated by non weight bearing The total treatment incidence among neonates in the area was 2 3 in 1 000 whereas the distribution differed widely according to place of birth A relevant referral and thereby treatment rate was only obtained among infants born in an obstetrical department No dislocations were overlooked among the referred neonates During the same period 13 infants born in the area had 17 dislocations diagnosed at a later age In 6 the dislocations had not been diagnosed at birth although the infants had been tested for it The correct technique of the Ortolani test is presumably as yet too little known outside the specialized hospital departments 12 of the 17 late cases were treated 9 with a good result

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Surgical Department, Koskela Hospital, Helsinki, Finland.

TROCHANTERIC FRACTURES OF THE FEMUR

Erik B. Riska

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The problems of hip fractures in the trochanteric region differ from those of intracapsular ones. Thus the incidences of pseudarthrosis and of necrosis of the femoral head are low in trochanteric fractures. On the other hand, the age of patients with trochanteric fractures is higher than that of patients with medial fractures of the femoral neck (Niemann & Mankin 1968, Riska 1970 a), and primary mortality grows with age (Alffram 1964, Riska 1970 a, Öhman et al. 1968). The older the patient, the greater is the importance of effective postoperative mobilization in avoiding complications such as thrombo-embolic diseases (Harris et al. 1967, Riska 1970 b). However, an early postoperative mobilization requires rigid osteosynthesis to permit full weight bearing on the injured limb (Holt 1963, Küntscher 1969, Massie 1964). Fractures in the trochanteric region have become increasingly common with the growth in the number of traffic accidents, as hip fractures originating in them are often trochanteric.

That the problem is extremely topical was proved by the congress arranged in October 1969 at Salzburg by Die Oesterreichische Gesellschaft für Unfallschirurgie, which was devoted exclusively to trochanteric fractures. At this conference special attention was paid to primary mortality and the importance of early mobilization in the prevention of complications was emphasized. To judge by the reports, new methods of fixation have been developed during the past years (Ender 1969, Giebel 1969, Holt 1963, Küntscher 1969, Massie 1964, Sarmiento 1967), but there were also advocates of conservative treatment (Kuderna 1969). Published reports show that results obtained under different conditions are at least to some extent contradictory. This motivates further investigation, as reports complement each other by elucidating different sectors and aspects of the problem.

Table 1 Patients with trochanteric fractures treated at Koskela hospital in Helsinki between 1961 and 1968

	Number of patients	Average age (years)	Total
Sex			
Male	21	72 5	210
Female	189	79 8	
Method of treatment			
Conservatively treated	64	81 5	210
Operatively treated	146	78 0	
Type of fracture			
Intertrochanteric	45	76 3	
Pertrochanteric	125	79 9	
Pertrochanteric			210
comminuted	34	79 3	
Subtrochanteric	6	76 3	

CLINICAL MATERIAL

The material consists of 210 patients with hip fractures in the trochanteric region treated at the Surgical Department of Koskela Hospital in 1961–1968 of whom 21 were men and 189 women The average age of the former was 72 5 and that of the latter 79 8 years Conservative treatment was given to 64 and surgical treatment to 146 The average age of the former group was 81 5 and that of the latter 78 years (Table 1)

Type of Fracture

The number of intertrochanteric fractures was 45 and that of pertrochanteric ones 125 Most of the stable fractures of the trochanteric region were found in these two groups in which the reconstruction of the calcar femorale was possible Pertrochanteric fractures of the comminuted type were found in 34 patients and these fractures were unstable with split calcar femorale (cf Dimon & Hughston 1967 Massie 1964) Fourteen of these patients had a severe comminuted fracture type with fracture line extending below the trochanteric region Six patients had subtrochanteric fractures (Table 1)



Figure 2a. A pertrochanteric comminuted fracture of the left hip in a woman 9[illegible] years old. The displacement is typical in old patients with comminuted fractures.

Figure 2b. Anteroposterior roentgenogram made of the same patient two weeks after reduction and fixation with a Jewett nail. The reduction of the fracture and placement of the nail are good.

of choice in most cases. Because of associated diseases only two out of six patients with a subtrochanteric fracture could be treated operatively.

COMPLICATIONS

The primary mortality (Table 2) was 40.2 per cent among conservatively treated patients (26 out of 64) and 14.4 per cent among operated patients (21 out of 146). According to examinations post mortem ten deaths were caused by pulmonary thromboembolism, six by cerebral apoplexy, eleven by pneumonia, three by coronary thrombosis, four by other heart diseases, five by universal arteriosclerosis

Table 2 Complications in the treatment of trochanteric fractures

Number of patients / Complications	Treated conservatively 64 Cases		Treated operatively 146 Cases		Inter trochanteric 45 Cases	Per trochanteric 125 Cases	Petro chanteric com minuted 34 Cases	Sub trochanteric 6 Cases	Total 210 Cases	
Primary mortality died within one month	26	40.2 %	21	14.4 %	8	32	7	–	47	22.8 %
Tromboembolic disease	6	9.3 %	12	8.2 %	3	12	3	–	18	8.6 %
Bronchopneumonia	17	26.5	11	7.5 %	3	20	1	1	28	13.3 %
Renal infections	1		10	6.8 %	2	8	1	–	11	5.2 %
Postoperative infection	–		4	2.7 %		4	–	–	4	
Pseudarthrosis	3		2		1	3	1	–	5	



Figure 2 a A pertrochanteric comminuted fracture of the left hip in a woman 9 years old The displacement is typical in old patients with comminuted fractures*

Figure 2 b Anteroposterior roentgenogram made of the same patient two weeks after reduction and fixation with a Jewett nail The reduction of the fracture and placement of the nail are good

of choice in most cases Because of associated diseases only two out of six patients with a subtrochanteric fracture could be treated operatively

COMPLICATIONS

The primary mortality (Table 2) was 40 2 per cent among conservatively treated patients (26 out of 64) and 14 4 per cent among operated patients (21 out of 146) According to examinations post mortem ten deaths were caused by pulmonary thromboembolism six by cerebral apoplexy eleven by pneumonia, three by coronary thrombosis four by other heart diseases five by universal arteriosclerosis

was inadequate Of the 103 patients whose fractures had verifiably united only 11 had been treated conservatively The hospital mortality of patients treated conservatively was high within five months 47 out of 64 died because of a poor general condition or associated diseases

RESULTS

Union was verified in 103 patients (Figures 3 a and b 4 a and b) and 81 were reconditioned and dehospitalized These patients walked as well as before the accident and the mobility of the joint was normal and

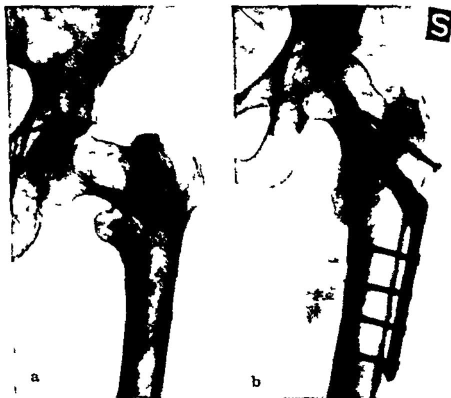


Figure 3 a A pertrochanteric comminuted fracture in a woman 90 years old Note the varus displacement and the fracture of greater trochanter

Figure 3 b Anteroposterior roentgenogram made eight months after reduction and internal fixation with a Jewett nail The greater trochanter has been fixed with a screw The fracture united in a good position

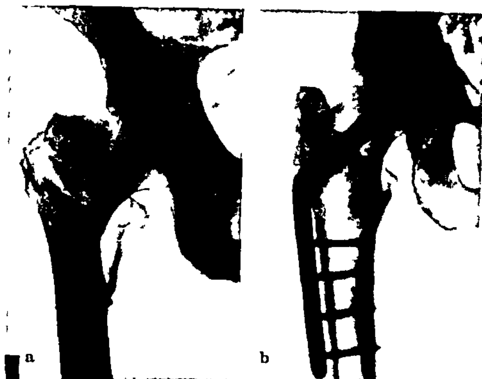


Figure 4 a A pertrochanteric comminuted fracture in a woman 73 years old This severe fracture had a typical displacement

Figure 4 b Anteroposterior roentgenogram made two months after reduction and internal fixation with a Jewett nail Note the good position of the fracture Ten months after surgical intervention the fracture was united the hip was symptomless and the patient walked without limp

painless Eight patients in this group had been treated conservatively Twelve patients remained in bed because of other diseases One patient of this group had been conservatively treated In five patients fractures had united in poor positions three of them had been treated conservatively and two had been operated on During hospitalization 87 patients died prior to consolidation and their results could therefore not be assessed

DISCUSSION

In spite of the high age of the patients (Table 1) and their poor general condition 81 patients (39 per cent) were reconditioned and sent home without symptoms in the hip joint Seventy three had been treated

operatively which speaks for surgical treatment as do other reports (Boyd & Griffin 1949 Dimon & Hughston 1967 Evans 1951 Massie 1964) Among those treated conservatively hospital mortality was high (73 per cent) Perhaps a few of them could have been reconditioned and sent home if they had been operated on The examinations post mortem showed that 23 patients had died of bronchopneumonia which suggests that infection remains a major lethal factor and would suggest increased prophylactic treatment with antibiotics Sixteen patients had died of pulmonary thromboembolism which indicates routine prophylactic anticoagulation treatment (Riska 1970 a b)

Early postoperative mobilization is essential only being possible with rigid fixation of the fracture (Holt Jr 1963 Massie 1964) This succeeds in stable fractures in which the calcar femorale can be reconstructed whereas the achievement of stability by osteosynthesis in fractures of the comminuted type is more difficult Recently some intertrochanteric and pertrochanteric fractures have been treated with a Küntscher nail inserted into the femoral neck through the medial femoral condyle (Figures 5 a and b) The patients were permitted early weight bearing of the limb and union was achieved with surprising rapidity without any complications Primary results have been good in a group consisting of more than fifteen patients which agrees with available reports from Germany (Giebel 1970 Küntscher 1970)

In unstable fractures the choice of method is more difficult Of the 34 patients in this group 16 were reconditioned and sent home with united fractures and symptom free hip joints However the seriousness of this fracture type is accompanied by the hight mortality rate within one month 8 patients died and 4 more died later in hospital Four remained bedridden because of other diseases In unstable trochanteric fractures osteotomy with medial displacement fixation has been advocated (Boyd & Griffin 1949 Dimon & Hughston 1967 May & Chacha 1968) This was done in only one instance As a method the reconstruction of the anatomy of the fractured bone seems more reasonable as suggested by Muller & Allgower Filling in the defect that have arisen in connection with the fracture with bone transplants has also been advocated (Müller Allgower & Willenegger 1969) but this would hardly reduce the non weight bearing period

A fracture fixed slightly in valgus seemed to unite more quickly than one fixed in anatomical position In this way it was possible at least to some extent to prevent progressive varus deformities from appearing during the convalescent period



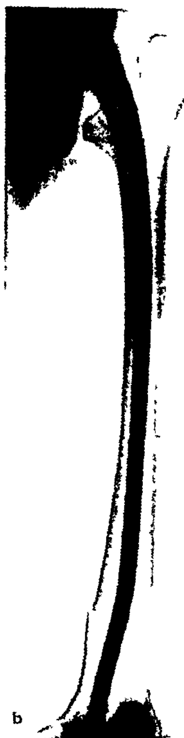


Figure 5 a. A pertrochanteric fracture in a woman 85 years. Note the typical varus displacement.

Figure 5 b. Anteroposterior roentgenogram of the same femur made one month after internal fixation with a Küntscher nail inserted into the femoral condyle after reduction of the fracture on the operating table under anesthesia. A small cortical fracture above the medial condyle appeared in connection with insertion of the nail. The patient walked on th day after the operation with full weight bearing on the injured limb. Two months after the operation the hip was [illegible] and the patient walked with at l mp and without a stick.

SUMMARY

The results of the treatment of trochanteric fracture of the femur have been reviewed on the basis of 210 patients treated at the Surgical Department of Koskela Hospital Helsinki during 1961–1968 Of these patients 21 were male and 189 female The average age of the men was 72 5 years and that of the women 79 8 years Conservative treatment was given to 64 and operative treatment to 146 patients

There were 45 intertrochanteric fractures 125 pertrochanteric fractures 34 unstable fractures of the comminuted type and 6 subtrochanteric fractures

In 64 cases treatment had to be restricted to traction and bed rest surgery being contraindicated by a poor general condition and associated diseases Osteosynthesis with the McLaughlin nail was done to 128 patients and with the Jewett nail to 16 patients Adequate follow up periods ranging from 9 months to 6 years were achieved for 112 patients in 103 cases the fractures were found to have united and treatment was concluded

Of those treated conservatively 26 out of 64 patients (40 2 per cent) died within one month The primary mortality of those operated on was 21 out of 146 patients (14 4 per cent) As shown at examination post mortem the most frequent causes of death were pneumonia pulmonary thromboembolism cerebral apoplexy and heart disease

Thromboembolic disease was found in 8 6 per cent Postoperative infections occurred in four operated patients (2 7 per cent)

Pseudarthrosis developed in 3 conservatively treated and 2 nailed patients

The fractures were found to have united in 103 patients of whom 81 were reconditioned and sent home In stable fractures efforts were made to reconstruct anatomical conditions especial attention being paid to the calcar femorale In unstable fractures a slight valgus position was found to be favourable for the consolidation The stability achieved with the McLaughlin nail was as good as that obtained with the Jewett fixed angle nail as long as the nail was fixed to the plate in a correct manner

The importance of rigid fixation in the treatment of trochanteric fractures has been emphasized At least in stable fractures this can be achieved with the new method by inserting a Küntscher nail into the femoral neck through the medial femoral condyle

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Surgical Department of Koskela Hospital Helsinki

PROSTHETIC REPLACEMENT IN THE TREATMENT OF SUBCAPITAL FRACTURES OF THE FEMUR

ERIK B RISKA

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Thanks to improved anesthesia the surgical treatment of hip fractures has replaced conservative treatment with traction and bed rest not least because patients must be mobilized early to prevent thrombo embolic disease (Harris Salzman & Desantis 1967 Riska 1970 b)

In which cases then should the primary treatment consist of endo prosthesis and what cases ought to be nailed according to earlier methods? Nicoll (1963) strongly recommends saving the femoral head by reducing the dislocated fracture and nailing Trueta (1968) and Harrison (1963) state that many of the patients develop capital necroses before long and Merle D Aubigne (1958) found necroses in more than 50 per cent of his cases Such figures suggest primary endoprosthetic surgery at least in older patients But necrosis of the femoral head does not necessarily need to trouble the patient (Boyd & Salvatore 1964 Fielding Wilson & Zickel 1962 Rehnberg 1965) and if it does it can be taken care of at the secondary stage Even a pseudarthrosis after a fracture of the femoral neck can remain symptomless (Boyd & Salvatore 1964 Rehnberg 1965) though most pseud arthroses cause pain and some compel patients to stay in bed This may be fatal to old patients Pseudarthroses can of course be prevented by primary endoprosthetic surgery but an endoprosthesis that has stayed put and given no symptoms may later get loose and cause the patient great discomfort necessitating further measures Thus late complications after endoprosthetic surgery have compelled us to pay more attention to the choice of treatment (cf Anderson Hamsa & Waring 1964 Parrish & Jones 1964)

These problems in the treatment of subcapital fractures of the femur will be discussed here in the light of 122 cases of endoprosthetic

Table 1 Prosthetic replacement in the treatment of femoral neck fractures at the surgical department of Koskela Hospital in 1961–1968

Age (years)	Moore endoprosthesis	Thompson endoprosthesis	Total patients
Under 45	–	1	1
45–49	1	–	1
50–54	1	–	1
55–59	4	–	4
60–64	2	–	2
65–69	17	4	21
70–74	17	6	23
75–79	24	6	30
80–84	16	4	20
85–89	15	–	15
90–94	4	–	4
Total	101	21	122

surgery At the same time a description will be given of the two methods of endoprosthetic replacement used today in our clinic

CLINICAL MATERIAL

The material consists of 122 patients with fractures of the femur treated in 1961–68 at the Surgical Department of Koskela Hospital Helsinki with endoprosthetic replacement surgery Of the patients 11 were men and 111 women 69 were over and 53 under 75 years of age (Table 1)

Indications for the Endoprosthetic Replacement Operation

In 107 cases endoprosthetic replacement was performed as a primary operation In 15 cases it was performed in the secondary stage in two because of the failure of conservative treatment and in 13 because of complications after nailing Of these 13 patients 11 had pseudarthrosis and two necrosis of the femoral head after nailing of a subcapital fracture Of 470 patients with fractures of the hip 158 had subcapital fractures of the Pauwels (1935) III type (Riska 1970 a) of whom 65 5 per cent were t[illegible] [illegible]ith endoprosthetic surgery In nine of 26 patients with fr[illegible] Pauwels II (Riska 1970 a) endoprosthesis was [illegible] unstable fracture (Table 2)

Table 2 Prosthetic replacement in the treatment of femoral neck fractures at the surgical department of Koskela Hospital in 1961–1963

Type of fracture	Total number of patients	Treated with endoprosthesis
Subcapital Pauwels I	41	4
Subcapital Pauwels II	26	9
Subcapital Pauwels III	158	103
Transcervical	29	4
Trochanteric	210	1
Pathological	6	1
Total	470	122

Associated Diseases

Many of the patients had a poor general condition at the time of the accident Even if early surgical treatment was considered essential for the prognosis in elderly patients with hip fractures they had to be treated adequately because of associated diseases before surgical intervention Universal arteriosclerosis in need of treatment was found in 50 patients heart conditions motivating the administration of digitalis in 39 senile dementia in 21 diabetes mellitus in 16 chronic kidney conditions in 15 and arterial hypertension in 10 patients 10 had a past history of cerebral apoplexy Organic malignant tumor was recorded in four patients

Operative Technique

The hospitalized patient was put in traction and surgical procedures were decided on only after preoperative treatment had been given by the physician Most patients were anesthetized through inhalation but when this was prevented by diseases of the circulation or of the respiratory tract spinal anesthesia was used Moore s (1952) endoprosthesis was applied in 101 cases and Thompson s (1954) prosthesis in 21 In 8 cases the endoprosthesis was fixed with methylmetacrylate A posterolateral incision was used in 96 and an anterior incision in 26 instances

The Posterolateral Approach (Southern Exposure)

The method was that described by Osborne in 1930, by Gibson (1950) and later by Moore (1959) If the endoprosthesis could not

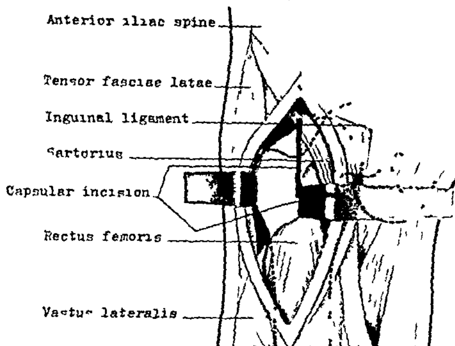


Figure 1 The anterior approach A straight incision is made on the medial side of the tensor fasciae latae muscle The sartorius and rectus femoris muscle are taken medially and the capsule is opened with an incision in the shape of an L If necessary part of the capsule is resected

firmly implanted into femur it was affixed with acrylic cement (Charnley Follacci & Hammond 1968) Patients were allowed to get up the following day though in some instances mobilization had to wait longer because of the patient s poor general condition

The Anterior Approach

The operation was performed with the patient on his back with the sound leg suspended from the ankle (about 30 cm) A straight incision was made into the anterior surface of the thigh in the region of the hip joint on the medial side of the tensor fasciae latae muscle The capsule was opened with a straight incision and distally across in the shape of an L (Figure 1) The opening had to be sufficiently high and if necessary part of the capsule was resected A Thompson prosthesis was preferred but if the correct size was missing a Moore endo prosthesis was used instead The limb was given hyperextension by

Table 3 Complications in the treatment of 122 patients with endoprosthetic replacement

Complications	Moore endo prosthesis 101 patients	Thompson endoprosthesis 21 patients	Total 122 patients	
	Cases	Cases	Cases	Per cent
Primary mortality died within one month	12		12	9 8
Postoperative infections	5	1	6	4 9
Thromboembolic disease	10	1	11	9 0
Late fracture of the femoral shaft	4	–	4	3 3

lowering the foot end of the operating table while the suspension prevented the healthy leg from following This made it easy to insert the endoprosthesis with or without acrylic cement Patients were ambulant on the following day and were allowed to bear full weight on the operated leg

Postoperative Complications

There were 12 primary deaths (9 8 per cent) Three patients died of pneumonia three of pulmonary thromboembolism two of cerebral apoplexy one of coronary thrombosis and one of a tumor of the adrenal gland Two patients were not examined post mortem

Six patients (4 9 per cent) developed postoperative infections (Table 3) Four could be treated with antibiotics without removing the endoprosthesis

A deep thrombophlebitis appeared in 11 patients (9 per cent) of whom three died primarily of pulmonary thromboembolism No routine treatment with anticoagulants was given prophylactically treatment was only begun when the thrombophlebitis had been diagnosed

Follow-up

Follow up periods comprised 4–7 years for 14 patients 2–4 years for 20 patients 1–2 years for 25 patients 6–12 months for 20 patients and 5–6 months for 19 patients Of the dead 12 died within one month and 12 within five months of the operation

Table 4 Results of treatment with endoprosthetic replacement

Result	Moore endo prosthesis	Thompson endoprosthesis	Total patients	
	Cases	Cases	Cases	Per cent
Excellent	37	12	49	40 2
Good	23	3	26	21 3
Fair	9	2	11	9 0
Poor	3		3	2 5
Died within five months after the operation	21	3	24	
Still in bed because of associated disease	8	1	9	
Total	101	21	122	

RESULTS

Results were classified into excellent good fair and poor by the following criteria

Excellent The patient walked almost without limp and without a stick and the mobility of the hip joint was normal There was no pain

Good The patient walked almost without limp indoors without and outdoors with a stick The mobility of the hip joint was good Stress caused periodic pain in the hip joint

Fair The patient had to use a stick when walking because of pain in the hip joint The ability to move about was poorer than before the accident The mobility of the joint was reduced by at least one third X rays showed that the position of the endoprosthesis was correct but there was a resorption area around the shaft of the endoprosthesis because of its loosening

Poor The patient had to use two sticks or crutches when ambulant There was pain in the hip joint both when walking and standing The mobility of the hip joint was reduced by about half and to judge by the resorp tion area in the X rays the endoprosthesis had loosened Changes suggesting osteoarthritis had appeared in the acetabular roof

Results were excellent in 49 patients (40 2 per cent) and good in 26 (21 3 per cent) Thus good results were obtained in 61 5 per cent of the operated patients Twenty four patients died within five months of the operation and nine stayed permanently in bed because of other simultaneous diseases (Table 4) Thus results could not be assessed for these 33 patients

Results were fair in 11 patients of whom 6 had loosening of the endoprosthesis Poor results were obtained in three patients of whom two had postoperative infections

Late Complications

Four patients operated on through a posterolateral approach had a late fracture of the femoral shaft following a fall (3 3 per cent) but results of the endoprosthetic surgery had been good One patient with a femoral mid shaft fracture was treated operatively with wire loops and was sufficiently reconditioned to be sent home Of three patients treated conservatively with traction and bed rest one remained bedridden and two were reconditioned and sent home after six months in hospital

DISCUSSION

Of 122 patients with fractures of the femoral neck treated in 1961–68 with endoprosthetic surgery 35 were operated before 1965 and 87 after January 1965 Thus the primary prosthetic replacement operation has become much more common in recent years especially as it is vital to mobilize aged patients as soon as possible after surgery to prevent the appearance of thromboembolic diseases Such diseases were found in only 9 per cent of the operated patients though their age was high (Table 1) The 15 patients with secondary endoprosthetic operations had long hospitalization periods which in itself means a prolonged period of reconditioning Nor were results as good as in patients with primary endoprosthetic operations That two operations were performed on 13 patients also affected the final result For these reasons in the past three years primary endoprosthetic replacement has been done in this clinic to most geriatric patients with a Pauwels III type fracture irrespective of the patient s age No biological age limit could be placed on endoprosthetic surgery as the procedure was chosen *in casu* according to the type of fracture and the patient s other diseases Especially patients with serious arteriosclerosis but also those with mental disease need rapid mobilization to avoid complications and in such cases endoprosthetic surgery is a good treatment of subcapital fractures The same conclusion was stated by Lunceford 1965

Above all postoperative complications must be avoided after endoprosthetic surgery The appearance of thromboembolic diseases can

be largely prevented by prophylactic treatment with anticoagulants (Harris et al 1967) Infections of the respiratory tract can also be largely avoided with effective antibiotics and physiotherapy To prevent loosening of the endoprosthesis it can be fixed to the femur with acrylic cement which thus helps to avoid one late complication A hip joint with endoprosthesis can of course develop other complications such as late hematogenous infections (Langenskiöld & Riska 1967) and they have to be encountered with sufficiently early effective and adequate treatment with antibiotics

After a successful endoprosthetic operation patients are as a rule more satisfied with the results than patients nailed. Perhaps this is a consequence of the fact that after nailing the postoperative treatment is more of a strain full weight bearing being forbidden for periods up to four months from the operation Moving on crutches is depressing In any case endoprosthetic surgery can prevent the development of pseudarthroses and necroses of the femoral head after subcapital fractures With improvements in operative technique late complications have also decreased after endoprosthetic surgery which speaks strongly for this procedure

SUMMARY

The treatment of subcapital fractures of the femur has been reviewed on the basis of 122 patients treated with endoprosthesis at the Surgical Department of Koskela Hospital Helsinki between 1961 and 1968 Of these 122 patients 11 were men and 111 were women 69 of them were over 75 years at the time of the accident and 53 were under 75 years 107 patients were treated primarily with endoprosthesis 15 with an endoprosthesis as a secondary procedure

Four patients had a subcapital Pauwels I fracture nine patients a Pauwels II type fracture and 103 patients a Pauwels III type fracture Four patients had a transcervical fracture one an intertrochanteric fracture and one a pathological fracture

101 patients were treated with a Moore endoprosthesis and 21 with a Thompson prosthesis 96 patients were operated on through a posterolateral incision 26 through an anterior incision

The primary mortality amounted to 9 8 per cent Postoperative infections occurred in 4 9 per cent thromboembolic diseases in 9 0 per cent Four patients had later fractures of the femoral shaft

For 14 patients the follow up was 4–7 years for 20 patients 2–4

years for 25 patients 1–2 years for 20 patients 6–12 months and for 19 patients 5–6 months 12 patients died within a month of the operation and 12 patients within five months

Results classified as excellent were obtained in 49 patients (40 2 per cent) good results in 26 patients (21 3 per cent) fair in 11 patients (9 0 per cent) and poor results in 3 patients (2 5 per cent) Twenty four patients died within five months and their results could not be assessed and 9 patients remained permanently bedridden mainly because of other simultaneous disease Thus good results were obtained in 61 5 per cent altogether

A primary endoprosthetic operation is indicated in most patients with a dislocated subcapital femoral fracture of the Pauwels III type, irrespective of the biological age of the geriatric patient providing there is no contraindication for operation. The discussion deals with current methods of treatment and with their indications

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Department of Orthopaedic Surgery and Department of Neuroradiology
Rigshospitalet Copenhagen Denmark

DIPLOPEDIA

KJELD SKOL ANDERSEN & HANS ROVSING

Accepted 5 iv 71

Diplopedia is a congenital malformation with complete or partial double-foot formation Only 19 examples of this malformation have been described in the literature during the past fifty years Apart from a series of 4 cases published by Gandolfi et al (1965) the reports have always consisted of single cases In view of the rarity of the condition we have found it of interest to report the following case

Bo aged 14 months Pregnancy and delivery were normal One sister who is normal Malformations of the nose and of both hands and feet were found at birth The nasal cavity was stenosed but no harelip or cleft palate was found The hands were flipper like, and 6 to 7 nail elements could be distinguished on both sides The thumb was missing bilaterally (Figure 1)

Both feet were extremely broad with the hind foot in a varus position and the forefoot in an adducted equino-position It was not possible to correct the abnormal position of the feet. 10 toe elements were found on both sides (Figures 2 and 3)

The spinal column chest thighs and upper arms showed normal osseous conditions radiologically The forearm was normal on both sides but both hands showed syndactylism of all fingers The number and structure of the metacarpal bones were normal and the proximal phalanges could easily be distinguished, but not the distal phalanges

Both thighs were rotated outwards with the knees in a varus position The lower leg consisted of 2 bones of apparently normal proportions one tibia like in the upper end the other pointing about 1 cm proximally to the first and crossing it in the middle of the diaphysis (Figure 4) The changes found were remarkably symmetrical and it was difficult to designate the longer bone The formation of a double tibia is one possibility The tarsus consisted of 2 heel bones 1 talus and 2 scaphoids on both sides together with ossification centres for 3 unidentified tarsal bones The right foot had 10 the left 9 completely or partially developed metatarsal bones with corresponding toes In both feet the metatarsal and phalangeal bones situated centrally were strongly built the size and strength decreasing peripherally (Figures 5 and 6)

Because of the severe deformities, amputation was considered to be the only possible treatment However corrective surgery was attempted first in the form

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Figure 4 Antero posterior radiogram of the pelvis and lower extremities

of removal of the medial part of the foot and tenotomy of the medial Achilles tendon The operation confirmed the radiological findings whereas the vascular and neurological conditions could not be further elicited

The most commonly encountered duplication of the extremities is polydactylism with an incidence of 0 05 to 0 1 per cent By comparison diplopedia is rare especially in the form demonstrated where the duplication includes forefoot as well as hindfoot As Weil (1924) pointed out the duplication always takes place around the pre axial ray analogous to conditions in the upper extremity (Werthemann 1952)

Interest in congenital deformities of the extremities has been increasing during the past decade though mainly in the skeletal deficiencies where O Rahilly s classification (1951) has contributed to a better understanding and treatment of these patients (Hall 1962) Treatment of congenital skeletal duplications is less complex but should be more individual for which reason centralized treatment would probably be advantageous

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Department of Orthopaedic Surgery Malmo General Hospital
University of Lund Malmo Sweden

ISOENZYMES OF LACTIC DEHYDROGENASE AND ESTERASES IN REGENERATING BONE

C Gudmundson & H Semb

Accepted 10 viii 71

The distribution of some enzymes in regenerating bone has been studied histochemically These studies have shown among other things an increased activity of alkaline phosphatases (Pritchard & Ruzicka 1950) oxidative enzymes (Balogh & Hajek 1965) and esterases (Raekallio & Makinen 1968) The lactic dehydrogenase isoenzymes in regenerating rabbit bone have been investigated by Bruce & Strachan (1967) Isoenzymes are varieties of an enzyme possessing the same substrate specificity but differing in electrical charge and/or molecular size

In a preliminary study on esterases in experimental fracture callus we found the isoenzyme pattern to differ in certain respects from that of normal bone (Semb & Gudmundson 1969) This paper concerns a continuation of that study of esterases including an oxidative enzyme lactic dehydrogenase

MATERIAL AND METHODS

Young adult rabbits weighing 2 5–3 0 kg were used The animals were anaesthetized with sodium pentobarbital intravenously Two centimeters proximal to the radiocarpal joint a defect was made in both radial diaphyses by removing a one centimeter long bone cylinder with a dental saw The bone tissue regenerating in the defect was studied after various intervals Seven groups of four animals were sacrificed at three six nine fourteen twenty-one thirty and sixty days post operatively The forearms were X rayed (Figure 1) and the tissue between the "fracture ends was dissected and kept on ice during further preparation The

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Figure 1 Experimental fracture of rabbit radius with a healing time of 0 day (left) 14 days (middle) and 60 days (right)

dissected material from each animal was prepared and analysed separately The radial bone cylinders removed were treated in the same way as the regenerating tissue and were used as control samples of normal bone

All blood was removed from the samples by rinsing them in cold isotonic saline The specimens were frozen in liquid nitrogen crushed in a cold steel mortar weighed and extracted overnight in isotonic saline at +4 The extracts were centrifuged at + 4 and 10 000 g for five minutes and the supernatants were used for the analyses (Semb 1971)

Determination of lactic dehydrogenase (LDH) activity and separation and identification of LDH isoenzymes were performed as described earlier (Semb 1971) The relative activity of the various LDH isoenzymes was measured in a Vitatron photometer with a scanning device and automatic recorder

Esterase isoenzymes were separated electrophoretically on starch gel according to Smithies (1955) A plexiglass electrophoresis tank was used Starch was heated in Ashton buffer pH 8 C after which the gel was evacuated and casted on a glass plate that was later cooled by running tap water during electrophoresis A constant current of 150 mA was used After the electrophoretic separation the various fractions were identified by incubation overnight at 37 in a substrate mixture of the following composition 1 ml one per cent α naphtyl acetate 1 5 mg Fast Red TR salt 50 ml of phosphate buffer pH 7 0 and 50 ml of distilled water Fixing was performed in acetic acid methanol and distilled water in the volumetric proportions 1 5 5

Specific inhibitors (eserine and diethyl p nitrophenylphosphate) were used to characterize the esterases After electrophoresis the gel slides were divided horizontally One of the slides was incubated in a 10 M solution of one of the inhibitors at room temperature for fifteen minutes before the two halves were incubated in the substrate mixture above described Enzyme inhibition was evaluated by comparing the paired slides

RESULTS

The total activity of LDH given as units/gram fresh tissue was very high in callus with a maximum value about a hundred times normal after nine days The LDH activity was still much increased after sixty

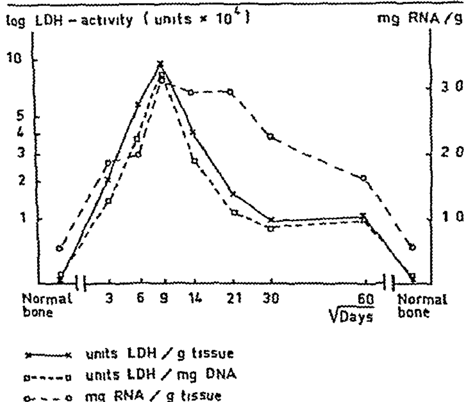


Figure 2 Total activity of LDH expressed as units/g fresh bone and as units/mg DNA respectively in regenerating bone of various age The concentration (mg/g fresh bone) of RNA in regenerating bone The concentration of DNA and of RNA (mg/g w t tissue) were taken from Deutsch & Gudmundson (In press)

days (Figure 2) There was a parallel but somewhat lower activity increase when the activity was expressed as units/mg deoxyribonucleic acid (DNA) There was a similar variation with time of the LDH activity and the RNA concentration (Figure 2) The values for the concentration of DNA as well as those of RNA in regenerating bone were taken from an investigation on regenerating tissue from the corresponding region in rabbits of the same weight as those used in the present investigation (Deutsch & Gudmundson 1971)

Figure 3 demonstrates the relative activity of the LDH isoenzymes of regenerating bone in various healing stages compared with that of normal bone from the diaphysis of the radius The percentage activity of LDH 1 was lower in regenerating bone especially after six to thirty



Figure 1. *Experimental fracture of rabbit radius with a healing time of 0 day (left), 14 days (middle) and 60 days (right).*

dissected material from each animal was prepared and analysed separately. The radial bone cylinders removed were treated in the same way as the regenerating tissue and were used as control samples of normal bone.

All blood was removed from the samples by rinsing them in cold isotonic saline. The specimens were frozen in liquid nitrogen, crushed in a cold steel mortar, weighed and extracted overnight in isotonic saline at +4°. The extracts were centrifuged at +4° and 10 000 g for five minutes and the supernatants were used for the analyses (Semb 1971).

Determination of lactic dehydrogenase (LDH) activity and separation and identification of LDH isoenzymes were performed as described earlier (Semb 1971). The relative activity of the various LDH isoenzymes was measured in a Vitatron photometer with a scanning device and automatic recorder.

Esterase isoenzymes were separated electrophoretically on starch gel according to Smithies (1955). A plexiglass electrophoresis tank was used. Starch was heated in Ashton buffer, pH 8.6, after which the gel was evacuated and casted on a glass plate that was later cooled by running tap water during electrophoresis. A constant current of 150 mA was used. After the electrophoretic separation the various fractions were identified by incubation overnight at 37° in a substrate mixture of the following composition: 1 ml one per cent α-naphthyl acetate, 15 mg Fast Red TR salt, 50 ml of phosphate buffer pH 7.0 and 50 ml of distilled water. Fixing was performed in acetic acid, methanol and distilled water in the volumetric proportions 1:5:5.

Specific inhibitors (eserine and diethyl-p-nitrophenylphosphate) were used to characterize the esterases. After electrophoresis the gel slides were divided horizontally. One of the slides was incubated in a 10^{-5} M solution of one of the inhibitors at room temperature for fifteen minutes before the two halves were incubated in the substrate mixture above described. Enzyme inhibition was evaluated by comparing the paired slides.

RESULTS

The total activity of LDH, given as units/gram fresh tissue, was very high in callus with a maximum value about a hundred times normal after nine days. The LDH activity was still much increased after sixty



Figure 4. Esterase isoenzymes in ten day old callus (left) and in normal diaphyseal bone (right) from the rabbit radius.

days. There was also a drop in the percentage activity of LDH 2 up to nine days. The relative activity of LDH 3 was increased from fourteen to thirty days. The activity of LDH 4 and LDH 5 rose to peak values at nine days. Still after sixty days the relative activity of LDH 5 was much elevated. At that time, however, the remaining enzyme fractions tended to become normal (Figure 3). By X-ray was demonstrated that mineralization was weak at fourteen days but seemed to be completed after sixty days (Figure 1). Thus the activity of slow moving isoenzymes (LDH 4 and LDH 5) increased and that of fast migrating (LDH 1 and LDH 2) decreased in young, insufficiently mineralized callus.

Ocular estimation of the esterase isoenzyme activity showed increased activity in all callus preparations. In normal rabbit radial bone the esterase isoenzyme pattern showed a predominance of two slow migrating fractions and a smaller fast moving anodic fraction. However, in regenerating bone the fast esterase isoenzyme was much more active than the slow fractions (Figure 4). With increasing maturity of the callus the fast zone was relatively weaker, resulting in a tendency towards normalization of the isoenzyme pattern.

Incubation in eserine of the gel plates after electrophoresis of extracts of healing and control bone did not result in inhibition of any

of the isoenzymes But treatment with diethyl p nitrophenyl phosphate inhibited all enzyme fractions

DISCUSSION

The occurrence of oxidative enzymes including lactic dehydrogenase has previously been demonstrated in fracture callus in the rat fibula Considerable enzymatic activity was found mainly in osteoprogenitor cells already after three days (Balogh & Hajek 1965) In the present investigation as in that by Bruce & Strachan (1967), a pronounced increase of LDH activity was found in regenerating bone In the present study maximum increase of enzyme activity was found after nine days when the callus was very poorly mineralized It is noteworthy that this maximal increase occurred at the time when the RNA concentration is maximal (Deutsch & Gudmundson 1971 Figure 2) and in later healing stages when the regenerating tissue was almost fully mineralized (Figure 1) the activity of LDH and the concentration of RNA curves declines almost simultaneously (Figure 2 Deutsch & Gudmundson 1971) The increased activity of LDH seems thus mainly to reflect the high rate of synthesis of organic matrix in healing fractures

In the present study increased activity of LDH in healing bone was demonstrated both in relation to tissue content (wet weight) and to the DNA content (Figure 2) Considering the constant relationship between DNA concentration and the number of cells (Enesco & Leblond 1962) this may indicate that the enzyme activity in regenerating bone was increased more than what could be explained by the increased number of cells in this tissue

Increased activity of esterases has been demonstrated histochemically very early in the granulation tissue of a fracture in rats (Raekallio & Makinen 1968) Also in the present investigation strong esterase activity was found early in bone healing It is thus evident that esterases are involved in the metabolism of regenerating bone before the mineralization process reaches its maximum There are two main groups of esterases non specific and choline As eserine known to inhibit choline esterases completely failed to inhibit any esterase fraction the identified fractions were probably non specific esterases The esterase inhibition by diethyl p nitrophenylphosphate and the failure of inhibition by eserine implies that the demonstrated esterases

in healing and control bone are of the non specific organophosphate sensitive type

The esterase isoenzyme pattern in regenerating bone showed a predominant anodic fast fraction This fraction is weak in normal diaphyseal radial bone in the rabbit This change in the isoenzyme pattern which tended to become normal with time might reflect the cell differentiation occurring during maturation of the callus

LDH isoenzymes are tetramers of two polypeptide subunits called H and M which are randomly combined to form the five *LDH isoenzymes* LDH 1 = HHHH LDH 2 = HHHM etc The polypeptide H is preponderant in tissues with mainly aerobic metabolism such as heart muscle while there is a preponderance of M subunit in tissues with anaerobic metabolism (Goodfriend & Kaplan 1964) In regenerating bone there was a decrease of LDH 1 or H subunits and an increase of LDH 4 and 5 M subunits both of which tended to become normal in the later healing stages This may imply a predominantly anaerobic metabolism in callus at a time when LDH activity and RNA concentration are at their highest and when there is a rich blood supply Anaerobic metabolism with a rich blood supply seems conflicting However relative ischaemia might occur despite increased blood flow when the metabolic rate is very high as in fracture repair (Gudmundson & Semb 1971) Thus a clinical conclusion stressing the importance of normal oxygen transporting capacity of the blood in patients with healing fractures may be drawn from the isoenzyme pattern demonstrated Against the other possible suggestion that the cells in young fracture callus for some reason should prefer anaerobic metabolism stands the well known clinical experience that impaired blood supply retards the rate of fracture union

The LDH isoenzyme pattern of callus in this investigation is incompatible with the results reported by Bruce & Strachan (1967) They studied the LDH isoenzymes in healing bone obtained from the rabbit mandible six to fifteen days after the defect had been made in the bone In control mandibular bone as in healing bone LDH 1 predominated This preponderance of LDH 1 however was less in healing bone where the relative activity of the other isoenzymes was much increased On the contrary in our investigation the slow moving isoenzymes (LDH 4 and 5) predominated in healing bone In their investigation the isoenzymes were separated on acrylamid gel but this cannot explain the conflicting results The difference in region from which the tissue was obtained mandible and radius respectively might

explain the difference in isoenzyme pattern though a pilot study by one of us (H.S.) revealed no significant difference of the LDH isoenzyme pattern in bone tissue from various tubular bones in the same individual.

SUMMARY

Isoenzymes of lactic dehydrogenase (LDH) and esterases were studied in bone regenerating in standardized osteotomies of the rabbit radius.

LDH isoenzymes were electrophoretically separated on agar gel and esterase isoenzymes on starch gel. The LDH enzyme activity (units/g wet weight) was substantially increased in fracture callus. The LDH activity per cell expressed as units/mg DNA was also increased in the same way. A parallel increase of LDH activity and RNA concentration was found.

LDH 4 and 5 were increased and LDH 1 was decreased in regenerating bone indicating a metabolism with relative ischaemia in healing fractures.

The esterase isoenzyme pattern of callus contained a predominant fast anodic fraction, that of normal bone a predominant slow fraction.

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Division of Orthopaedic Surgery State University of New York
Downstate Medical Center Brooklyn New York
Department of Physics, New York University New York and
Department of Anatomy Columbia University
College of Physicians and Surgeons New York

THE INFLUENCE OF ELECTRIC CURRENT ON BONE REGENERATION IN VIVO*

L S Lavine I Lustrin M H Shamos & M L Moss

Accepted 20 v 71

Current research indicates that stress induced electrical potentials play an important role in directing the architectural and structural integrity of bone It is felt that this electromechanical phenomenon is due to a classical piezo-electric effect originating in shearing forces on the bone collagen (Fukada 1956 Shamos & Lavine 1963 1964 1967)

Because electromechanical effects appear to be vital in explaining much orthopaedic physiology several groups first the Japanese (Yasuda Noguchi & Sata 1955) and then the Americans (Shamos & Lavine 1963 1964 1967 Bassett et al 1964) have been active in studying their various parameters In the course of these researches direct current effects on bone physiology have proved to be of great interest

There have been attempts to construct an ideal experimental model (Bassett et al 1964 Minkin et al 1968 O'Conner et al 1969) using direct current with variable results One model which is most useful and has been described by our group (Lavine et al 1969) has been published in the recent literature

This experimental power unit (Figure 1) consists of a 1 4 V mercury cell connected in series with a 174 k resistor The leads from the battery pack are copper wire fastened to platinum electrodes with silver epoxy cement Alligator clips are placed in one of the leads for monitoring The wire which goes into the bone is insulated with shrinkable rubber tubing

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* Presented in part at the Sixth European Symposium on Calcified Tissues, Lund Sweden August 21 1968

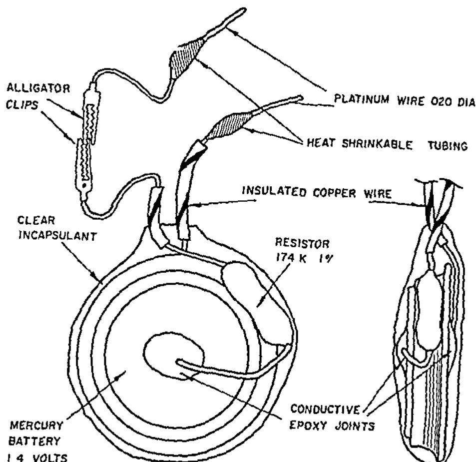


Figure 1 Diagram of experimental unit

It is the purpose of this paper to describe an *in vivo* study on rabbits using our experimental model showing the effect of direct current in the range of 2–4 microamperes on a bony defect produced in rabbit femora

MATERIALS

Ninety one 2–3 kg white Dutch pelted rabbits were anesthetized with intravenous nembutal. The rear extremity was shaved and prepared under sterile conditions The middle one third of the femur was exposed and the periosteum stripped from the femur Two drill holes (1 97 mm) were made through one cortex only 15 mm apart a third drill hole (2 77 mm) was produced midway between the two and acted as the experimental defect Platinum electrodes were inserted into the 1 97 mm diameter drill holes The wires and battery capsule were buried sub

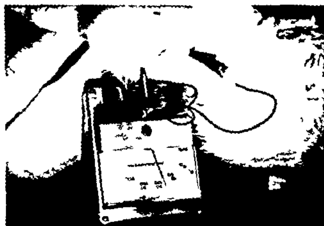


Figure 2 Circuit completed through microampere meter showing method of monitoring current



Figure 3 Animals and electrical apparatus encased in plaster cast for protection "Alligator" clamps used for monitoring current connected to complete electrical circuit

cutaneously "Alligator" clamps were brought out through an incision in the skin of the back. (These clamps could be connected to a microamperemeter and current readings obtained, Figure 2) The circuit was completed by connecting the two alligator clamps A spica cast was applied for the protection of the bone and the electrical apparatus (Figure 3)

Two to four microamperes of direct electric current crossed the experimental defect for periods ranging from one to three weeks. Animals were sacrificed at one

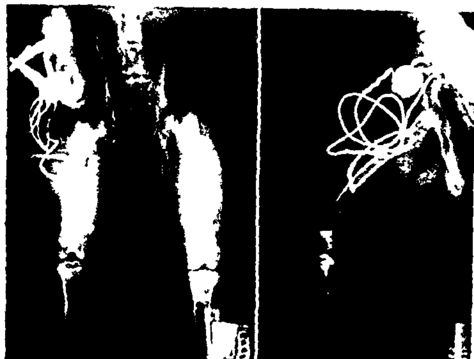
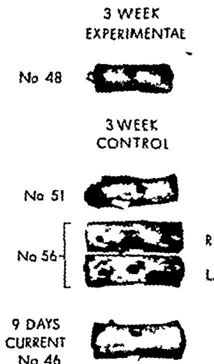


Figure 4 X ray *showing platinum electrodes* in situ *in the cortex of the femur*

Table 1

Weeks		Mean current in microamperes	Number of animals: Healed (Hole >75% filled)	Partially healed (Hole >75% filled)	No healing
1	Exp	3 1		1	14
	Cont	–			6
2	Exp	2 2		6	–
	Cont	–			8
3	Exp	2 5	13	5	
	Cont	–		6	17
4	Exp	–			
	Cont		1	1	
5	Exp	1 8	1		
	Cont	–			
6	Exp	1 3	1		
	Cont	–	4		

Figure 5 Gross comparison of the experimental defect in three week experimental and control animals



two and three week intervals The femur was removed and the experimental defect was observed grossly and microscopically for new bone formation

The experimental group (animals having constant current passing through the experimental defect) consisted of 15 animals in the one week group 8 animals in the two week group 23 animals in the three week group and 1 animal each for five and six weeks a total of 48 animals The control group (animals treated in the identical manner as the experimental group except that no electric current passed through the experimental defect) consisted of 43 animals 6 rabbits in the one week group 8 rabbits in the two week group 23 rabbits in the three week group 2 rabbits for four weeks and 4 rabbit for six weeks

RESULTS

The results are summarized in Table 1 Our findings indicate that

1 Three weeks of current at 2 5–3 5 microamperes is most conducive to the production of new bone formation

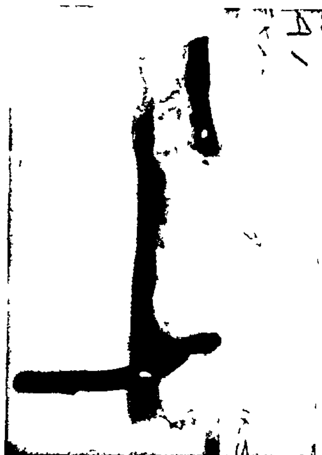


Figure 6 Grossly completely healed defect in a three week experimental animal (see Figure 10)

2 Infection interferes with healing by direct electric current
3 Three week experimental animals showed approximately the same amount of bone formation as six week controls
4 Slight variations occurred in the ultimate healing at three weeks in the experimental group However as compared to control animals the changes were conclusive

Figures 5 and 6 represent the gross appearance of 3 week experimental animals as compared to controls The gross difference is obvious The slight variation in healing can be seen by comparing Figure 6 to Figure 5 Figures 7 8 9 and 10 represent the microscopic picture seen in three week experimental and control animals The variations in healing observed grossly in the experimental group are reconfirmed microscopically



Figure 7 A control section three weeks postoperative The lumen of the cavity is filled with a loose tissue not significantly different from the adjacent medullary tissue The outer surface of the core shows some evidence of postoperative reactive osteogenesis

DISCUSSION

The application of electrical currents as outlined in the experiment enhances the normal calcification process How can one account for the mechanism of activation of many different cells by this specific stimulus? Recent experimental evidence indicates that among the control mechanisms involved in bone physiology electrical effects probably share in the well known biochemical factors operative at the cellular level

Transmission of signals from one cell to the next is accomplished by a combination of chemical and electrical means This transmission is a highly specialized function mediated through a complex of biological and physical factors It does not seem unreasonable to suppose that the local changes may be effected architecturally by the rapid orientation of the fibrous structures and also through the action of calcium ion It is known that dissociation of bound calcium can be induced



Figure 8. This specimen three weeks experimental differs from that shown in Figure 7 in that the defect is filled with a mass of trabecular bone which seems to be continuous with similar tissue type found within the medullary cavity. Little reactive bone formation has occurred on either the periosteal or the endosteal surfaces.

electrically and that the calcium ion has profound effects on cellular and enzyme functions.

It is important to state that this discussion includes only a few of the key factors responsible for bone healing. There is no question that other physical, chemical and biological factors are involved in bone regeneration.

SUMMARY AND CONCLUSIONS

1. Observations have been carried out in 91 rabbits on the effects of controlled amounts of direct electric currents on the healing of an experimental defect.

2. Direct current in the experimental group increased the normal healing as compared to the control animals by roughly a factor of two.

3. Obvious clinical implications can be inferred from this experi-



Figure 3 A good degree of osseous repair has filled the experimental cortical defect in this specimen after three weeks of application of direct current There is a continuity between this tissue and the reactive peri and endosteal formation

mental work The value of electric current on the enhancement of bone healing in congenital pseudoarthrosis of the tibia and long standing non union of fractures is presently being investigated

ACKNOWLEDGMENTS

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Figure 10 This specimen 3 weeks experimental disclosed a far advanced degree of osseous repair filling the experimental defect (see Figure 6)

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Orthopaedic Hospital, Depts I and II and Department of Physical Medicine
Copenhagen Denmark

MELORHEOSTOSIS

Report on 5 Cases with Follow-up

F Hove & B Sury

Accepted 17 v 71

Melorheostosis was described for the first time in 1922 by Leri & Joanny and the first case in Denmark was reported by Bertelsen (1940)

The condition is presumably more common than indicated by the approx 150 cases on record (Campbell 1968) but nevertheless rare enough for a report of 5 cases with follow up to be of interest

It is a peculiar and interesting fact that the disease has existed for centuries Lester (1967) found radiological changes characteristic of melorheostosis in an Eskimo skeleton from Alaska dating from about 500 A D

The most characteristic change is hyperostosis affecting one or more bones In typical cases the radiological changes are easy to recognize They have been likened to melting wax dripping down the sides of a candle The bony thickening may extend into the epiphyseal area of the bone as streaks but the joints are seldom involved (Figure 1)

Biopsy specimens have been taken in about 20 cases (Morris et al 1963) and the histological findings have been extremely uniform In the sclerosed bone the Haversian system is of irregular arrangement with thickened densely anastomosing trabeculae As a rule there is cellular fibrous tissue in the medullary canal and around proliferating bone Fibrosis of subcutaneous tissue perivascular obliteration of vessels and atrophy of the skeletal muscles have also been observed by Morris et al (1963)

SYMPTOMS SIGNS AND COURSE

The most common symptoms and signs of melorheostosis are pain paraesthesiae and sensory disturbances over the involved bones The



Figure 1 Case 3 Melorheostosis of the right tibia

pain is of skeletal nature It may be quite mild but it is what usually makes the patient seek medical attention

Bony deformity is sometimes present Not infrequently the patients have noticed thickening or increased length of the affected bones right from childhood (Campbell et al 1968) The limbs are most often affected as a rule unilaterally but any bone may be involved Early mild muscular atrophy is common Cutaneous changes are rare Lymphoedema haemangioma and pigmentation of the skin have been described in a few cases

The disease has been diagnosed at all ages but mostly in the young age groups In a few cases it has even been present at birth Its aetiology and pathogenesis are unknown but the findings made so far are most suggestive of a congenital origin probably around the 4th foetal week (Campbell et al 1968)

Among diseases of bone which may give rise to differential diag

nostic problems previous authors have emphasized Albers Schonberg s osteopetrosis osteopoikilosis carcinomatous metastases with an osteoplastic tendency chronic osteomyelitis Paget s disease Recklinghausen s disease and syphilis

Melorheostosis must be considered definitely benign At any stage the changes may become stationary If progression occurs it is very slow There have been no systematic studies to elucidate the long term prognosis Treatment is symptomatic

CASE REPORTS

1 T A (Case rec 2931/63) A female aged 29 The only symptom was pain in the left ankle Physical examination in 1963 disclosed no abnormality X rays revealed melorheostotic changes in the left tibia at the distal metaphysis, on the fibular and dorsal aspect of the bone

At *follow up* 5 years later the condition had improved Now the patient rarely had pain in the left ankle There was still no objective abnormality and X ray examination showed the changes to have remained unchanged since 1963 Routine radiography of the right foot and ankle region showed typical changes similar to those on the left There have *not* been any symptom or signs from the region of the right ankle

2 L T J (Case rec 8143/64) A male aged 16 who had previously been in good health The patient complained of pain in the lower part of the right thigh especially when bending the knee No objective changes of the limbs X ray examination of the femora showed melorheostosis of both shafts medially and dorsally

At *follow up* 4 years later the condition had considerably improved There was only intermittent pain in the lower part of the right thigh No treatment had been required X ray examination showed melorheostosis of *both femora* medially and dorsally of the same appearance as previously

3 L S H (Case rec 389 60) A male aged 64 previously in good health The patient presented himself f r the first time 8 years ago because of severe pain on the p sterior asp ect of the right lower limb mild paraesthesiae but no sensory disturbances or pare es There v a slight limitation of movement in the right hip e pecially on internal rotation and abduction No ymptoms from the right knee X ray examination revealed severe chang s of the right femur involving the entire shaft centrally medially and dorsally but most marked in the lower part There were also severe changes of the right tibia invol ing the entire shaft from the proximal condyle to the listal part No changes of the left lower limb The patient received symptomatic treatment with a favoural le effect

At *follow-up* 8 years later the patient ha l been symptom free during the past 7 years Physical examination did not show any abnormal ty and on X ray exa minat on the appearance were un hanged

4 E N J (Case rec 5801 66) A female aged 46 During the past 10 years she ha l had periodical pain in the regi n of the left houlder left arm and fingers Alwa s free mobility f th j int of the left arm No parae thesiae o pareses

Radiography revealed melorheostosis at the transition between the metaphysis and shaft proximally in the left humerus on the ulnar and dorsal aspect The patient received symptomatic treatment and the pain yielded

At *follow up* 2 years later the patient was still symptom free and X rays showed unchanged appearances

5 U I S (Case rec 5930/56) A female aged 43 previously in good health except for the present disease For about 5 years she had been having increasing pain in the right knee No complaints from the left knee X ray examination revealed melorheostosis distally medially and dorsally on the femoral shaft on *both* sides, but *more marked on the right*

At *follow up* 17 years later the condition had appreciably improved There was still pain in the right knee but not as severe as previously The patient had not received any treatment in the meantime Physical examination did not reveal any changes of the right lower limb X rays of the left and right femora showed the appearances to be unchanged

At the time of follow up all 5 patients were subjected *inter alia* to the following laboratory tests ESR Hb serum creatinine alkaline phosphatases serum calcium and serum phosphorus The results were normal in all cases

DISCUSSION

The material comprises 5 patients whose disease was diagnosed during the period 1935–1967 Two were males and three females and at the time of the diagnosis they ranged in age from 16 to 64 The age at onset of the disease cannot be stated as the symptoms need not appear until long after the disease process has started The follow up examinations were performed in 1968

In our cases the diagnosis was based upon the radiographic findings but it is usually vague uncharacteristic pain at the site of the affected bones which makes the patient consult a doctor However the bone pain may be absent For instance 3 of our patients (Cases 1 2 and 5) had symmetrical melorheostotic changes in the contralateral limb but only symptoms from one

The symptoms have subsided during the follow up period from 1–10 years in all the patients

We have not observed radiological progression of the osseous changes

There is a tendency for the osseous changes to be localized at the site of the metaphysis and dorsally in the long bones

The soft tissue changes described in the literature were not present in any of our patients presumably because all the cases were mild On

the other hand Campbell et al (1968) among their 14 cases had 5 fairly severe ones—showing massive osseous changes with secondary articular contractures and deformities

ACKNOWLEDGEMENT

Our thanks are due to M Schalimtzek Chief Radiologist for his kind help in reading the X ray films

SUMMARY

The authors report 5 cases of melorheostosis with follow up Unlike most previously reported cases the present ones improved There was no instance of contractures or deformities The diagnosis was based upon the radiographic findings in all cases The findings are briefly discussed in relation to those reported by previous authors

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Martina Hansens Hospital, Sandvika, Norway

CHRONIC OSTEOMYELITIS

A Report of Fifty Cases Treated with Lincomycin (Lincocin®)

BERNHARD PALS

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Chronic osteomyelitis still represents a subject for discussion at orthopaedic meetings (Nordisk Ortopædisk Forening's 34th Assembly 1968) and articles in orthopaedic literature (Taylor & Maisley 1970, Rowling 1970). The cause is that chronic osteomyelitis still represents a challenge to the orthopaedic surgeon, the disease including an ischaemic as well as an infectious component.

Surgery is required to remove the ischaemic tissues which comprise both necrotic bone tissue and scar tissue. Removal of bony abscess cavities may require chiseling of non-necrotic bone to prevent retention by forming a gutter instead of a well. Foreign bodies should usually be removed, but in the case of infected fractures it may be advisable to postpone the removal of osteosynthesis material until the fracture has healed. The operative field may be closed primarily, perhaps after the bone cavity has been filled with bone chips, muscle or subcutaneous tissue, or the wound may be left to secondary healing following the methods of Winnett Orr (1927) and Trueta (1939). It is often advisable to perfuse the wound with physiologic saline solution either as a continuous drip or with several forced perfusions per day. This can be continued for from several days to more than a week. Skin transplantation to cover raw bone surfaces, or after the wound has closed, may become advisable.

Which form of local treatment should be chosen in the actual case must be decided by the surgeon in each case. Perhaps in this decision it is more a question of medical art than profession.

The fight against the infection is based upon a strengthening of the patient's general condition and chemotherapy. Sufficient food both in quality and quantity, extra doses of vitamins and correction of anaemia if necessary by blood transfusions are factors to remember. The

chemotherapy should be based on a drug that fulfils the following criteria (Herrell 1968)

1 It should concentrate well in bone
2 It should be highly active against penicillinase producing as well as nonpenicillinase-producing staphylococci
3 The development of resistance if it does occur should be slow or delayed
4 It should show little or no cross resistance with the commonly used antibiotics
5 It should be relatively nontoxic permitting its prolonged use in the treatment of chronic osteomyelitis

Before chemotherapy is started it is important to try to find the causative organisms and their sensitivity to different chemotherapeutic agents Since we are not so pressed for time in chronic osteomyelitis as in acute osteomyelitis it is possible to perform adequate sensitivity studies Immediate culture on agar gives the best opportunity for positive results In recurring osteomyelitis without sinus formation it is advisable to permit the organism time to grow with production of pus and not arrest its onset too early The chemotherapy should probably be started before the operation but the ultimate results do not seem to be better by instituting therapy earlier than a few days before operation The dosages should be sufficient to give the proper blood concentration for the drug to enter the bone lesion in necessary concentration despite the reduced vascularity The drug may also be given locally e g as an addition to the perfusion fluid

When the results of the treatment of chronic osteomyelitis are evaluated it should be kept in mind that chronic osteomyelitis like the Sleeping Beauty can awake after many years of sleep It is therefore better to use solely descriptive expressions as no symptoms no signs or healed and not say cured

In 1969 (Holloway) reviewed the literature on the treatment of osteomyelitis with lincomycin (Lincocin®) and reported a cure rate of 79 6 per cent in 172 patients with chronic osteomyelitis The purpose of this paper is to report the results with lincomycin therapy in 50 consecutive patients with chronic osteomyelitis or arthritis excepting three with lincomycin resistant organisms There is no intention to evaluate the effectiveness of lincomycin compared to other drugs It may however be mentioned that there are good reasons to think that Lincocin fulfils Herrell s criteria for chemotherapy

CLINICAL RESULTS

The patients were between 5 and 76 years old with a history of osteomyelitis between 3 months and 55 years The histories are summarized as follows

Therapeutic misadventures in		18 cases
osteosynthesis	8 cases	
other operations	8 –	
intraarticular injections	1 –	
wire traction	1 –	
Acute osteomyelitis in		14 –
Infected compound fracture in		10 –
Secondary infection in active tuberculous joint in		5 –
Secondary infection in earlier tuberculous joint in		3 –

The osteomyelitis was localized in hip or femur in 25 of the 50 cases Specimens from all patients were examined for infecting organisms Staph aureus was found in 44 cases alone in 34 cases and mixed with other organisms in 10 In 4 cases organisms other than Staph aureus were found and in 2 cases there was no growth All cases but 1 were examined for their sensitivity to lincomycin and found positive Phage typing was done in only about one third of the cases

The dosage was usually 500 mg lincomycin four times a day to adults continuing about four weeks following healing then the dosage was reduced to 500 mg twice a day Children received smaller dosages Patients were treated locally with radical saucerization with less radical operation or even without any operation According to the condition primary closure of the wound was employed with or without postoperative perfusion of the wound or the patients were treated according to Winnett Orr and Trueta s method

Of the 50 patients 47 healed and 41 remained healed for an observation period lasting from nine months to three years ten months In 6 patients the condition recurred but following new treatment 3 healed once more and have remained healed for one year ten months to two years eight months

The results were more impressive for patients who were *operated* and particularly for those who were operated most radically than for patients who were not operated This deserves particular attention since the groups are not identical—the patients who were most radically operated were those who were estimated to be the most serious

cases This observation supports the assertion that chronic osteomyelitis is as much an ischaemic as an infectious problem

Operation	Total treated	Healed and remained healed	Healed but recurred	Failure
Saucerization	17	16	–	1
Other operations				
Sequestrectomy	8	7	–	1
Currettement incision				
removal of nail	11	8	3	–
No operation	14	10	3	1
	50	41	6	3

The *duration of lincomycin treatment* was significant This applies for the total length of time as well as for the time following healing Again the patient groups were not identical but those who were treated for a long time usually were those who were estimated to be the most serious cases In spite of this 27 out of 29 cases with more than three months duration of lincomycin treatment following healing remained healed whereas only 5 of 9 less serious cases who were treated less than one month after healing remained healed

Duration of medication after healing	Total healed	Remained healed	Healed but recurred
More than 3 months	29	27	2
1–3 months	9	9	–
Less than 1 month	9	5	4
	47	41	6

The 3 patients with recurrence who healed after another lincomycin treatment that was continued more than one month after healing have remained healed

To decide whether the operation or the duration of medication was most important for the results the patients should be grouped in operated and not operated and these groups be divided in patients given drugs for more than three months one to three months or less

than one month With not more than 50 patients altogether the groups get small In addition the groups are not identical as e g the patients supposed to be most seriously affected are within the operated long time treated group This study thus does not justify any conclusion or comparison of the importance of operation contra duration of medication With this reservation some figures may be reported

Duration of medication after healing	Total healed	Remained healed	Healed but recurred
	Operated patients		
More than 3 months	23	21	2
1–3 months	6	6	
Less than 1 month	5	4	1
	34	31	3
	Not operated patients		
More than 3 months	6	6	
1–3 months	3	3	
Less than 1 month	4	1	3
	13	10	3

The *bacteriological condition* was of importance as the results were best in patients who had only lincomycin sensitive organisms Altogether nine patients had both lincomycin sensitive and lincomycin resistant organisms and were also *treated with other chemotherapy* e g anti tuberculosis drugs The lincomycin sensitive organisms usually disappeared but the mixed infection continued in some cases

Lincomycin sensitivity	Total treated	Remained healed	Healed but recurred	Failure
Sensitive alone	35	31	4	–
Sensitive and not sensitive	9	5	1	3
Sensitivity not tested or no growth	6	5	1	
	50	41	6	3

The *duration of the disease* had no apparent effect on results For example the group of 10–55 years history includes 4 patients with a duration of more than 50 years another 4 with a duration of 40–49 years and altogether 13 of the 14 had a duration of more than 20 years

Duration	Total treated	Remained healed	Healed but recurred	Failure
10–55 years	14	12	1	1
1–10 years	20	17	3	–
Less than 1 year	16	12	2	2
	50	41	6	3

The *cause of the osteomyelitis* its *localization* or the *age of the patient* had no influence on the results as far as this could be judged from the few patients studied

The 6 cases which recurred and 3 which failed to heal should be examined a little more closely

1 In 3 of the cases with sensitive organisms but which recurred the reason was probably that the medication was stopped within two weeks following healing One case also had foreign bodies in the form of osteosynthesis material but since he had serious heart disease and his osteomyelitis had improved so much that it bothered him only minimally he did not undergo operation

2 The fourth patient with only sensitive organisms who recurred probably had insufficient saucerization since there were huge masses of new bone around the infected Thompson prosthesis

3 In the fifth case with recurrence the reason was probably also deficient operation since we did not find any sequestrum but two sequestra were found by a second operation following the recurrence after which he has remained healed for eight months

4 The sixth patient had a tuberculous arthritis of a sacroiliacal joint with mixed infection with Staph aureus She had two recurrences the first may have been caused by stopping treatment less than two weeks after healing The cause for her second re-

currence may have been that she did not take her drugs for long periods of time

5 Two of the cases which failed to heal had mixed infections with Pseudomonas aeruginosa During treatment the Staph aureus disappeared and the condition improved considerably but the Pseudomonas did not disappear

6 The last patient had a tuberculous knee with Staph aureus and in addition had cancer of the skin covering a large area in front of the knee

Finally it should be mentioned that all recurrences appeared within the first year following healing namely after one one four six eight 10 and 11 months inclusive of the case who had her second recurrence after eight months On the other hand no recurrence was observed after 11 months in 40 patients observed for more than one year from healing

SUMMARY

Fifty patients were treated with lincomycin because of chronic osteomyelitis or arthritis 47 healed and 41 remained healed for periods of observation lasting between nine months and three years ten months Of six patients with recurrence three healed and have remained healed for one year ten months to two years eight months following a second treatment

The results were superior if the patient underwent radical operation with saucerization and when the chemotherapy was continued at least for one month and in serious cases for more than three months after healing

In patients with mixed infections the lincomycin sensitive organism usually disappeared but the resistant organism did not always disappear in spite of treatment with adequate chemotherapy

The cause of osteomyelitis its localization and the length of duration had no influence on the result 13 of the patients had a duration longer than 20 years 8 longer than 40 years and 4 longer than 50 years

The causes of recurrence and failure to heal are probably inadequate duration of medication following healing or insufficient operation or mixed infection with resistant organisms

All recurrences appeared within one year after healing and no recurrences appeared in 40 patients observed for more than one year

CONCLUSIONS

Lincomycin has given good results in this series of 50 patients with chronic osteomyelitis and/or arthritis It does not obviate the need for operation but the chemotherapy should be supplemented with removal of dead and ischaemic tissues We would encourage other investigators to report their findings with the concomitant application of lincomycin and appropriate surgical procedures in the treatment of this often discouraging and recurrent condition

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Tulane University School of Medicine
Division of Orthopaedic Surgery New Orleans, Louisiana U S A

PROGNOSIS OF POSTERIOR DISLOCATION OF THE SHOULDER

ALAN ROBERTS & JACK WICKSTROM

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The occurrence of three posterior dislocations of the shoulder at Charity Hospital during 1968 aroused interest in this problem The charts of all shoulder injuries requiring admission were reviewed from 1941 at Shreveport s Highland Hospital from 1942 at New Orleans Charity Hospital from 1945 at the Ochsner Clinic from 1950 at Shreveport s Confederate Memorial Hospital from 1953 at the New Orleans Veterans Administration Hospital from 1960 at the New Orleans Public Health Hospital, from 1964 at New Orleans Southern Baptist Hospital from 1964 at New Orleans Touro Infirmary from 1966 at Shreveport s Schumpert Memorial Hospital and from 1967 at Kessler s Air Force Hospital In addition private orthopaedists were solicited for patients who had been treated for this dislocation Forty two posterior dislocations of the shoulder were found This study is presented to ascertain the characteristics complications and prognosis of posterior dislocations of the shoulder

DIAGNOSIS

Posterior dislocation of the shoulder is reported to be infrequently seen and frequently misdiagnosed Characteristic histories are shoulder pain and/or disability preceded by convulsion electric shock or a force *applied to the anterior aspect of the humeral head or to the long axis* of a flexed adducted and internally rotated humerus Physical examination may reveal (1) the head of the humerus to be prominent *posteriorly with a corresponding flatness anteriorly* (2) prominent coracoid (3) the arm is held in internal rotation or neutral position (4) limited abduction and (5) absent external rotation Recurrent *posterior shoulder dislocation* is said to usually cause little impair



Figures 1A and B. A. Normal arch formed by axillary border of scapula and posterior margin of the humeral neck and shaft; shoulder in reduced position. B. Moloney's line showing the posterior dislocation.

ment of motion or pain. The above history and/or physical findings should alert the examiner to the possibility of a posterior dislocation of the shoulder.

Roentgenographic findings are diagnostic with axillary views which demonstrate the posterior position of the humeral head relative to the glenoid. In addition to the axillary view the transthoracic lateral is also diagnostic. However, the quality of this roentgenogram is not as predictable as the axillary. With a transthoracic view of good quality the scapulohumeral arch is visible. This arch is formed by the axillary border of the scapula and the posterior margin of the humeral neck and shaft. Normally the arch is graceful. On posterior dislocation this arch is disrupted and becomes a sharp angle. Dorgan calls the interruption of the normal scapulohumeral arch Moloney's line (Figure 1A and B).

Although the diagnosis is usually not recognized on the anteroposterior roentgenograms, certain suggestive signs may be present.

1. *Internal rotation of the humeral head* (Figure 2) is indicated by the absence of the greater tuberosity whose sharp outline is present when the humerus is held in external rotation.

2. *Absence of the half moon overlap* (Figure 2) occurs when the humeral head does not overlap the glenoid. Normally the head of the humerus overlaps the glenoid resulting in a half moon appearance.[7]

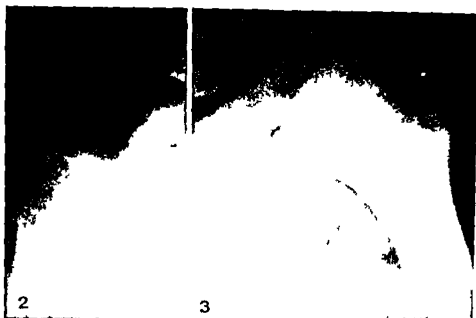


Figure 2 See text on suggestive signs seen on anteroposterior roentgenograms

Figure 3 Velpeau position prior to reduction note the upward displacement of the humeral head in relation to the glenoid

3 *Flattening of the medial aspect of the humeral head* (Figure 2) occurs due to internal rotation of the humerus In the neutral or externally rotated position the medial outline is convex In posterior dislocation this convexity becomes flattened The flattening corresponds to McLaughlin s operative findings that there was a deep vertical defect in the anterior aspect of the humeral head which was situated just medial to the lesser tuberosity

4 *Reverse Velpeau or Velpeau position* (Figures 2 and 3) refers to downward or upward subluxation of the humeral head in relation to the glenoid respectively

5 *Positive rim sign* (Figure 2) indicates that the distance between the anterior rim of the glenoid and the lesser tuberosity becomes greater than six millimeters with posterior dislocation

6 *Cystic or hollow appearance of the humeral head* (Figure 2) is due to the greater tuberosity being anteriorly rather than laterally when the x ray is being taken

CLASSIFICATION

Posterior dislocations of the shoulder have been classified by Dorgan into three types (1) rotational subluxation where the posterior glenoid lip is indenting the humeral head (2) subacrominal or retroglenoid and (3) subspinous Nobel has described an additional type the rare posterior subglenoid dislocation

CLINICAL MATERIAL

Data on forty one patients with posterior dislocations of the shoulder were analyzed as to sex age type of violence associated injuries, neurovascular complications length of follow up delay in diagnosis, treatment and results.

The male female ratio was two and four tenths to one The ages ranged from fourteen to seventy eight years Twenty four patients sustained their initial posterior dislocation of the shoulder between the ages of fourteen and thirty seven years However this injury is not limited to the young as four patients were in their eigth decade when they first dislocated their shoulder

The causes of the dislocations are major trauma seizures and ordinary activity Laxity of ligaments would appear to be a predisposing factor Twenty nine patients sustained posterior dislocations of the shoulder following major trauma the most common being a fall One patient sustained bilateral posterior dislocations following a ship explosion Eight patients had convulsions which caused their dislocations Two patients had brachial plexus injuries sustained at birth One patient dislocated her shoulder while bending down to tie her shoe laces and one patient h d suffered from bilateral shoulder dislocations since childhood.

There were nineteen associated fractures Fifteen patients had compression fractures of the humeral head One patient sustained an associated fracture of the greater tuberosity One patient had a fracture of the ipsilateral humeral head One patient had a fracture of the ipsilateral clavicle and one patient a fracture of the contralateral right second metacarpl in addition to the compression fracture of the humeral head

Two patients had neurologic complications One had a transient radial nerve palsy which cleared three months after the injury the other patient had an axillary nerve pal y which was detected one month after the injury Sensation over the deltoid returned six and one half months after the injury with motor impairment still being present two and one third years after the injury

Length of follow up for the forty one patients ranged from one day to sixteen and three quarter years Average length of follow up was 2? 7 month Sixteen patients ha l foll w up of eighteen m nths or more Ten patients had medical supervision for les than two months

Twent even patients had their dislocation diagnosed on admission Delay in diagnosis for the remaining patients ranged from three days to seven years

TREATMENT

Of the forty one patients twenty four had conservative therapy Eleven patients had surgical repairs of their shoulder dislocations Six patients were lost to follow up

After closed reduction shoulder immobilization ranged from two to eight weeks depending on the physician in charge Three patients refused to be immobilized after reduction Immobilization was accomplished by Velpeau dressing shoulder spica sling and swath Richard belt and airplane splint Nine patients had recurrences after this conservative therapy and five of these recurrences occurred in patients whose shoulders were immobilized for less than three weeks Three patients were immobilized for five and one half six and eight weeks respectively The remaining patient s treatment for his initial dislocation is not known Of the nine patients eight were thirty seven years of age or younger Four of the patients were female and five male One patient initially had an anterior dislocation which after surgical repair re urred posteriorly One patient two years prior to the *diagnosis of a posterior dislocation of the shoulder had an anterior shoulder repair* One week after his posterior shoulder arthroplasty an anterior shoulder dislocation was diagnosed and reduced without surgery Two patients with initial posterior dislocations recurred anteriorly Confirmatory roentgenograms on these last four patients are not available

RESULTS

Shoulder function was graded excellent good fair or poor An excellent result meant that the injured shoulder could not be distinguished from the normal shoulder by the examiner A good result meant there was no pain but shoulder motion was not equal to the normal shoulder However the slight limitation of motion did not prevent customary activities A fair result meant there was discomfort and the limitation of motion prevented some customary activities A poor result meant there was pain and the limitation of motion prevented most activities

Fourteen patients treated conservatively without recurrences were analyzed Results were excellent in five patients (ages twenty two twenty six forty fifty nine and sixty one years) good in four patients (ages thirty one thirty six thirty seven and thirty nine years) fair in *three patients (ages fifty four seventy three and seventy seven years)* and poor in two patients (ages fifty five and seventy eight years)

Eleven patients underwent fifteen operations for recurrences pain and/or old dislocation Various procedures used include posterior Putti Platt osteotomy of glenoid neck with posterior shoulder arthroplasty posterior bone block Neer prosthesis Reverse Bankhardt subscapularis lengthening and L Episcopo procedure Shoulder dislocations recurred after posterior bone block muscle tightening and Reverse Bankhardt repair Excellent results were obtained with the



Figures 54 B and C A and B Admission X rays of subglenoid type of posteri r disl cation with fracture of the greater tuberosity C, 6 months after dislocation was reduce l showing soft tissue cal ‹ fication in s ıpraspinatus ten lon

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Figure 4 Retroglenoid type of dislocation with the humeral head sheared into two separate parts

One question which should be answered is Do the different types of posterior dislocations of the shoulder have the same prognosis? It would appear that the least amount of damage to bone and soft tissue occurs with the rotational subluxation type Damage is increased with the retroglenoid and subspinous types The rare posterior subglenoid type causes the most damage If prognosis depends on the amount of damage the rotational subluxation type would have the best prognosis and the posterior subglenoid type of posterior dislocation of the shoulder (Figures 5A B and C) would have the worst prognosis

Analysis of data relating to patients shows that the presence of associated fractures may have delayed diagnosis of the posterior dislocation Faulty or late diagnosis may be avoided by axillary and/or transthoracic roentgenograms

Prior to the current report there had been presented in the literature only one patient with an associated neurologic complication which was transient However two of the patients in this series had neurologic deficits It had been assumed by some authors that since the dislocating humeral head s position was posterior this complication was most rare Neurovascular complications may be caused not only by the dislocating head but also by the trauma causing the dislocation Therefore it is







Figures 5A, B and C. A and B. Admission X rays of subglenoid type of posterior dislocation with fracture of the greater tuberosity. C. 6 months after dislocation was reduced showing soft tissue calcification in supraspinatus tendon.

suggested that thorough examination may disclose additional instances of neurovascular complications.

With immediate diagnosis, reduction and immobilization for three weeks, the prognosis of initial posterior dislocations of the shoulder

should be good. The greater the delay in treatment the poorer the results. Recurrence of the dislocation is unlikely after the age of fifty. Our data suggest that the functional results are good to excellent in patients under forty years of age and fair to poor in patients over fifty five years of age. However, two patients fifty nine and sixty-one years of age had excellent results.

The use of various surgical procedures implies that no single operation is generally accepted. It also suggests the difficulty of obtaining predictable success with any given method. Since more than one anatomic lesion can predispose to recurrent posterior shoulder dislocation, the surgical repair selected must take this into account. Tears or laxity of the posterior shoulder capsule, defect in the posterior glenoid rim and/or forced internal rotation of the arm are some of the factors which must be considered in selecting the proper procedure. Cadaver experiments have shown that forcible internal rotation of the arm produces a tear in the posterior portion of the capsule. This tear allows the shoulder to dislocate posteriorly. The inciting cause is the strong contraction of the subscapularis. Wilson has treated one patient with a recurring posterior shoulder dislocation with lengthening of the subscapularis tendon and a posterior bone block. The patient is thirty three months postoperatively without a recurrence. The posterior bone block is no longer visible on roentgenogram. Wilson feels that reduction has been maintained by removing the inciting cause. The authors conclude that in addition to surgical repair of the posterior capsule or posterior bone block, lengthening of the subscapularis tendon should be done.

Management of old unreduced posterior shoulder dislocations should be surgical if there are no medical contraindications. The authors are in agreement with Carroll who holds that functional shoulder fusions in poor position are undesirable. *Old unreduced dislocations should* have an open reduction, a posterior bone block and/or posterior repair of the capsule if prior to surgery the shoulder can be reduced under general anesthesia. Lengthening of the subscapularis tendon should also *be done. If the dislocation is not reductible a prosthesis or shoulder* fusion is indicated.

SUMMARY

Forty-one patients with posterior dislocations of the shoulder are analyzed with respect to age at time of injury, sex, associated injury, neurovascular complications, treatment, results, length of follow up

and delay in diagnosis The results after treatment are affected by the patient s age Good function occurs in the younger patients Recurrence of the dislocation is uncommon when the initial dislocation occurred after the age of fifty The authors conclude that the initial dislocation should be immobilized for three weeks in abduction extension and external rotation The recurrent posterior shoulder dislocation should be managed surgically with lengthening of the subscapularis tendon The old unreduced posterior shoulder dislocations should have a posterior bone block and/or posterior repair of the capsule if prior to the surgery the shoulder can be reduced under general anesthesia Lengthening of the subscapularis tendon should also be done If the dislocation is not reducible a prosthesis or shoulder fusion is indicated

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Department of Anaesthetics, Lasarettet, Skellefteå, Sweden

PROLONGED EXTRADURAL ANAESTHESIA WITH BUPIVACAINE AT LUMBAGO AND SCIATICA

OLAV KNUTSEN & HANS YGGE

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The treatment of pain in the back, better defined as lumbago with or without sciatica, is a problem all doctors are confronted with. Hardly any benign pain condition torments the sufferers more. It results in mental strain in the form of insomnia, immobilization, "tablet eating" and possibly treatment by doctor, manipulator or quack.

There are few symptom complexes that can be treated in so many different ways. Common to all the methods is the object of freeing the patient from pain, of mobilizing him and of getting him back to work. To attain this, symptomatic and operative treatment is applied.

Extradural anaesthesia is a form of treatment described as early as the beginning of the present century (Cathelin 1901, Caussade & Queste 1909). It has since had positive criticism from a number of authors in different countries (Coomes 1961, Cyriax 1961, Eriksson 1962, Goebert et al. 1960, Korkeila 1966, Nolte & Puente Egido 1969). Correctly carried out, the method presents slight risks irrespective of whether the sacral or the lumbar path is chosen to deposit the anaesthetic in the extradural space. Cyriax (1961) reported 20 000 cases treated with extradural anaesthetic, where only three showed mild complications, all of which regressed. Coomes (1961) treated 20 ambulatory cases and found in a comparative investigation that the convalescence period averaged 11 days, whereas for 20 conservatively treated cases the period was 31 days.

The anaesthetic has also been combined with hydrocortisone preparation with good results. Goebert (1960) obtained excellent results in 73 per cent of 113 cases. Eriksson (1962) reported 21 cases treated with prolonged extradural anaesthesia. Of these, 16 became symptom free, the others proved to have disc degeneration except for one with a mental condition.

At Skellefteå hospital prolonged extradural anaesthesia since 1966

has been an increasingly appreciated method for the treatment of lumbago and sciatica

MATERIAL

Our material consists of 96 patients 45 women average age 49 5 years (21 to 83 years) and 51 men average age 50 8 years (29 to 70 years) Sex and age distribution is shown in Figure 1 The 96 patients were given a total of 116 doses of the anaesthetic Anaesthesia block was induced in 16 patients on two occasions and in one patient on four occasions In 1966 there were 18 in 1967 30 in 1968–1970 68 The latter 68 blocks were carefully noted on special forms whereas information concerning the first 48 blocks was obtained from the patients case records which in some instances resulted in insufficient information Thus we cannot account for all 116 blocks

All patients were treated at the medical clinic except for one who was admitted to the surgical clinic

The 116 blocks were induced on the following indications lumbago sciatica 91 sciatica 15 lumbago 10

The symptom complexes were divided into the following groups

Lumbago sciatica pains in the lumbar region radiating into one or both legs

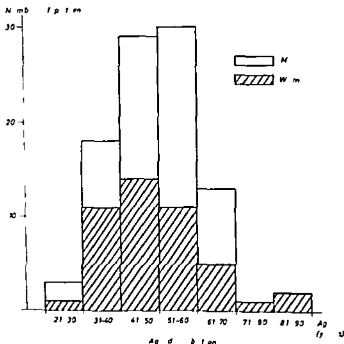


Figure 1

Sciatica pains localized to the gluteal region radiating into one or both legs

Lumbago only dull dead pain in the lumbar region

The material consisted of patients who had been referred to the hospital or admitted from the hospital clinics All patient were moderately to severely immobilized and suffered pain also in lying position resulting in insomnia and considerable consumption of analgesics as well as injection preparations

METHOD

We used Tuhoy needle usually applied in the interstice between the 3rd and 4th lumbar vertebrae The extradural space was identified by the "loss of resistance method whereupon 10 ml 0.25 per cent bupivacaine with adrenaline 1 200 000 (Marcain Adrenalin®) was injected A Portex extradural catheter was introduced through the needle so that *circa* 5 cm was estimated to be in the extradural space The other end of the catheter was provided with a Viggo s membrane coupling which was fixed with plaster to the patient s chest After half an hour s observation of among other things blood pressure the patient was transferred to the ward A new dose of the anaesthetic was injected through the membrane coupling when the effect of the previous dose had worn off The size of the iteration doses did not exceed 10 ml

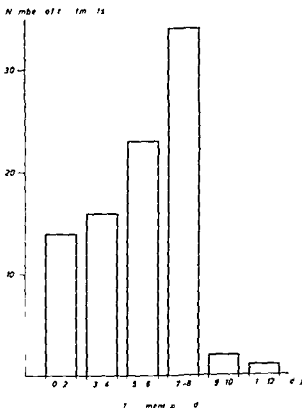


Figure 9

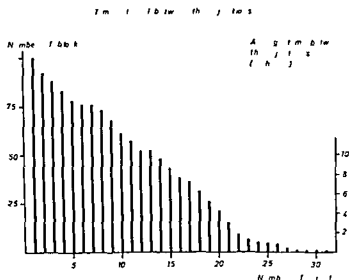


Figure 3

and the effect of the immediately previous dose was the deciding factor for the size of the current dose These injections were given by the nurses in the ward The patient was not allowed to leave his bed during the first half hour immediately after the injection thereafter if possible the patient was mobilized The catheter was usually withdrawn on the 8th day or earlier In individual instances the treatment continued longer

RESULTS

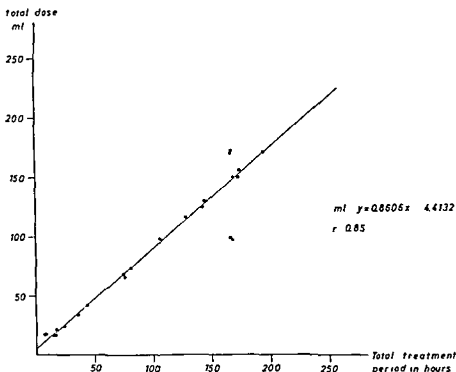
The following parameters in the material were examined

a The length of treatment period for each patient (Figure 2)
b The time intervals between the injections (Figure 3)
c The total amount of anaesthetic given to each patient (Figure 4)
d The total amount of anaesthetic given per day and patient (Table 1)
e The time interval before mobilization of the patients
f The relation between effect and X ray finding (Table 2)
g Complications (Table 5)
h Changes in blood pressure
i Toxic liver effect

a Figure 2 shows the treatment periods for 90 extradural anaesthesias In one case the maximum treatment period amounted to 10 days and 8 hours The catheter was withdrawn within 24 hours in 8

Table [illegible] Correlation of effect and X ray findings

Effect of injection treatment	Spondylosis	Spondylosis + disc degeneration	Disc degeneration	X ray/without visible changes	X ray/not carried out	Number of blocks	Per cent
None	0	3	3	2	0	8	6 9
Moderate	1	2	5	1	4	13	11 2
Good	1	8	8	8	3	28	24 1
Very good	15	23	6	10	7	67	57 8
Number of blocks	17	42	22	21	14	116	100
Per cent	14 6	36 2	19 0	18 1	12 1	100	



Relat on between treatment per od and total dose
Figure 3

blocks were determined beforehand (Table 3) Cases with complications of the type that necessitated removal of the catheter were designated "no effect All six patients (two of whom had blocks on two occasions) with no effect are specified in Table 4 Table 2 shows that almost 82 per cent of the blocks had good to very good effect

Table 3 Definition of the basis for appraisal of effect

Very good effect	Immediate pain relief Mobilization and exercises were begun without appreciable difficulties Discharge without or with onl insignificant symptoms
Good effect	Slight to moderate symptoms during the treatment Mobilization and exercises with moderate difficulty Discharge with remaining but fundamentally relieved symptoms
Moderate effect	Visibly noticeable improvement Difficulties with mobilization and exerci es Discharge with moderate but less symptoms
No ffect	Slight relief during the treatment or no relief Much difficulty with mobilizati n No improvement at discharge

Table 4. Cases where no effect was achieved

Sex	Age	Diagnosis	X ray/finding	Treatment period (days)	Complications	Comments
♂	45	Lumbago Sciatica	Disc degeneration	2	Saddle block anaesthesia	
♂	46	Lumbago Sciatica	Disc degeneration	8	-----	After 4 days new catheter. Treatment continued for 7 days
♀	48	Lumbago	Spondylosis Disc degeneration	2	Headache	
♀	67	Lumbago Sciatica	Spondylosis Disc degeneration	2	-----	After one day new catheter. Treatment continued for 3 days. Operated 1964 for adenocarcinoma recti. No metastases
♀	56	Lumbago	No changes	6	Pain where catheter introduced	Treated 1964 at psychiatric clinic. Diagnosed psychastenia + polysymptomatic
♀	41	Lumbago Sciatica	No changes	7	Paresis in right leg	Total paresis of the leg after each injection

Sex	Age	Diagnosis	X-ray/finding	Effect	Treatment period (days)	Complications	Comments
♂	45	Lumbago Sciatica	Disc degeneration	None	2	Saddle block anaesthesia	
♂	48	Lumbago	Spondylosis Disc degeneration	None	2	Headache	
♀	37	Sciatica	Disc degeneration	Good	8	Headache	Treated 1967 at psychiatric clinic Diagnosed Reactio hysterica
♀	56	Lumbago	No changes	None	6	Pain where catheter introduced	No local reaction *Treated 1964* at psychiatric clinic Diagnosed psychasthenia + depression + polysymptomatic
♀	50	Lumbago Sciatica	Disc degeneration	Moderate	6	Pain where catheter introduced	No local reaction
♀	41	Lumbago Sciatica	No changes	None	3	Paresis	Total paresis in right leg after each injection
♀	35	Lumbago Sciatica	Spondylosis	Very good	6	Paresis	Paresis in both legs after each injection
♂	48	Sciatica	No changes	Good	7	Tremor	Tremor only after primary injection
♂	68	Lumbago Sciatica	Spondylosis Disc degeneration	Very good	7	Felt cold after 3 days	No local reaction Catheter withdrawn New catheter introduced after one week
♂	56	Lumbago Sciatica	Spondylosis Disc degeneration	Very good	6	On 6th day temp 38 C 100 1) (Cause ob cure)	No local reactions

g No case with really serious complications was found nor was there any case with signs of infection or of total spinal anaesthesia The bladder paresis described by Belfrage & Raabe (1970) in connexion with prolonged extradural anaesthesia at partus was not observed by us Table 5 reports 10 patients with complications all of which regressed spontaneously before discharge from the hospital No complications were observed in 4 patients who suffered from diabetes mellitus Change of catheter was made in 12 patients within one week The cause of this was leakage in the catheter tubing coupling joint or because the catheter had been occluded or in one instance had slid out

h Blood pressure conditions were recorded during the first hour after the primary injection and after the first injection in the ward In 58 patients the blood pressure fell after the primary injection an average of 14 7 ± 1 4 per cent The maximum blood pressure fall was 43 7 per cent three patients showed no change in blood pressure and in another it rose by 18 2 per cent

Changes in blood pressure after the first injection in the ward were recorded in 55 patients The fall in blood pressure averaged 12 5 ± 1 0 per cent One patient had a reduction in blood pressure of 26 0 per cent one showed no change and two showed an increase of 4 5 per cent No statistically guaranteed difference could be demonstrated between the fall in blood pressure after the primary injection and the fall after the first injection in the ward

i 62 patients were examined to find out whether during the treatment there were any changes in the thymol reaction Takata s reaction alkaline phosphatases and GPT content Changes were observed only in alkaline phosphatases and GPT and these were completely within the limits for normal values

DISCUSSION

Although different opinions prevail concerning the aetiology and treatment principles there is none the less one common goal for all who treat bad backs to make the patients symptom free

For the most difficult cases of lumbago or sciatica we used continuous extradural block which proved satisfactory both to the patient and to the doctor Because of our positive results with only the minimum of complications this form of treatment has become routine with us

In animal experiments bupivacaine has proved to be essentially

more tissue irritating than mepivacaine it also has four times as high acute toxicity (Henn & Brattsand 1966) On the other hand bupivacaine is normally given clinically in a concentration four times lower than mepivacaine We could never find any signs of aseptic inflammation nor any signs of liver injury after the use of bupivacaine 0 25 per cent with adrenaline

In two cases the catheter was withdrawn on the third and the sixth day respectively because of rise in temperature for some obscure reason In one case a new catheter was reintroduced within one week No relation could be found between the rise in temperature and the treatment in progress Diabetes mellitus was not found to be a contraindication The risk of infection in the richly vascularized peridural tissue is apparently small To reduce the risks of infection careful sterilization was naturally observed moreover an anaesthetic with long duration was chosen This meant longer intervals between injections Earlier comparable studies have shown that bupivacaine has considerably longer duration than mepivacaine and lidocaine In our material we found an average duration of 8 hours 45 minutes between the injections This corresponds well to earlier investigations (Watt Rose & Atkinson 1968 Ekblom & Widman 1966 Lund 1965 Hollmen 1966 Nolte & Puente Egido 1969)

Tetracaine has been proved to cause 66 per cent more paresis than bupivacaine in 0 5 per cent solution (Bromage 1969) In agreement with this the patients in our material showed no noticeable pareses *or loss of sensibility in the lower extremities except for two We could* not find any explanation for these two but they perhaps were sensitive to the anaesthetic

At the introduction of the Tuhoy needle the interstice that we could most easily identify was used usually that between the 3rd and 4th lumbar vertebrae and the needle point was directed cranially There is no guaranteed criterion for the direction the catheter takes in the extradural space (Moore 1965) Thus it is possible that in the patient who developed saddle block anaesthesia the catheter went caudally and produced the same anaesthesia as at sacral block

We did not hesitate to use the treatment for three patients who had earlier been operated on for disc degeneration Two of them were operated on two occasions The effect on two of the three was very good and on one good There were no difficulties in applying the catheter except for one where we did not succeed until a renewed attempt was made a day later

The frequency of patients with tremor seems to depend on the amount of adrenaline (Ervin 1964). We had one patient with tremor who was successfully treated with 25 mg pethidine i.v. The highest recommended single dose of bupivacaine is 150 *mg but we never* found it necessary to administer more than 25 mg, and the highest 24 hour dose was 150 mg. Thus doses far below the expected risk of toxic effect were used.

We had two patients with temporary headaches. Evans (1930) reported that in connexion with extradural anaesthesia an increased intrathecal pressure arose which can possibly cause headache. We did not observe any changes in blood pressure that called for medical treatment, nor did any patient complain of symptoms that could be referred to changes in blood pressure.

The amounts of anaesthetics given daily and the time intervals between the injections varied only insignificantly. We failed to find with bupivacaine the tachyphylaxis that Moore (1965) describes in connection with lidocaine and mepivacaine.

Our criterion for applying block for lumbago and sciatica was solely the intensity of the pain and the degree of immobilization. We find it impossible in some cases to apply the recommendations found in the literature concerning solely strict bed rest and analgesics in the acute phase (Thompson 1970). We noted in some patients *threatening decubitus induced by pronounced immobilization in* connexion with severe pain. Prolonged extradural block resulted in dramatic pain relief and almost immediate mobilization. Thus early X ray examination could also be carried out, whereupon patients with demonstrated disc herniation could be referred to a special clinic. As Coomes (1961) showed, there is a shorter recovery period for patients *treated with extradural block than for those treated conservatively.* A pain circle is interrupted and perhaps a form of spontaneous reposition takes place. Perhaps the results could be further improved if different forms of treatment were combined (Kaltenborn & Brodin 1966).

Thus we consider that the prolonged extradural anaesthesia with bupivacaine is an attractive form of treatment for backache. Complications are few, slight and reversible. However, we do not wish to express an opinion about the possible therapeutic effect of the method. What we do is to keep the patient free from pain and mobile. In this way we avoid the conventional analgesics, which have a doubtful effect and sometimes severe side effects.

We have moreover a distinct impression that most of the patients

treated in this way do not return to the hospital complaining of backache. We are planning at present a more detailed examination of sick listed periods and frequency of recurrences.

SUMMARY

116 prolonged extradural blocks in 96 patients with lumbago or sciatica are reported. We used the "loss-of resistance" method. The anaesthetic was bupivacaine 0.25 per cent with adrenaline 1:200 000. The patients were mobilized on average 65 minutes after the primary injection. We found good to very good effect in about 82 per cent of the patients. The treatment period was more than 8 days for only 4 patients. Iteration intervals of the anaesthetic averaged 8 hours 48 minutes. The average dose of anaesthetic per patient and day was 15 ml; the total average dose was 99.2 ml. The fall in systolic blood pressure was statistically significant and amounted to 15.2 per cent after the primary injection and 13.1 per cent after the first injection in the ward. The material includes six "no effect" cases and ten with complications, all of which regressed. No toxic liver effect was found. There were no disadvantages shown when using the method on patients with diabetes mellitus or patients earlier operated for disc herniation. Tachyphylaxis was not noted. The usefulness of the method by itself or in combination with other treatment principles is discussed.

ACKNOWLEDGEMENT

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Department of Orthopaedic Surgery O Odense Hospital
Odense Denmark

ATYPICAL HIP CLICK IN THE NEWBORN

Jørgen Sommer

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If dislocation of the hip is diagnosed by Ortolani s test in a newborn a normal hip will be obtained by reduction and fixation in a plaster cast in the Lorenz I position (frog position) for 3 months (Gregersen 1969 Lauritzen 1971) Therefore an exact diagnosis has to be made within the first week of life If the Ortolani test is positive and reproducible there is no doubt about the diagnosis and the treatment But if the test reveals laxity or the so called dry atypical click there will be doubt as to whether treatment is necessary The dry hip click is heard in Ortolani s test and is felt as a dry crunching or crepitation but the hip is stable and not dislocatable and a certain laxity may be present

MATERIAL

In the Department of Orthopaedic Surgery O Odense the number of neonates treated for congenital dislocation of the hip up to 1965 was twice that expected according to the general incidence of this condition

On reviewing the case records it was found that about half the treated infants had in fact had the so-called dry hip click After 1965 newborns with dry hip clicks were not treated but followed clinically At the same time the prospective study to be reported below was started

The material comprises all newborns referred from the Obstetrical Department of the Odense Hospital with suspected hip disease during the 2 year period May 1965 to 1967 During this period 5060 infants were born who were examined by a midwife and a doctor immediately after birth Infants who did not have normal hips were examined in the Department of Orthopaedic Surgery O within the first 4 days of life This disclosed 17 with dislocation of the hip and a positive Ortolani test (0 3 per cent) and 99 with dry hip click but stable hips – 2 per cent or six times the number of those with dislocations

Among the patients with dry hip clicks the distribution by sex and side affected is largely the same as for the patients with congenital dislocation of the hip ie twice as many girls as boys and twice as many left sided as right sided

The 99 infants with dry hip click were seen once weekly at first and after the

first month once every other week until the hip click disappeared but they received no treatment In 60 per cent the click disappeared in the first month of life and after the second month only 10 per cent still had clicks At the age of 1 year only one patient still had the click.

The incidence of dry hip clicks immediately after birth may be expected to exceed 2 per cent as some clicks may have disappeared within the first 4 days of life i e before the examination in the orthopaedic department

Table 1 Dry hip click in 99 newborns
Sex and side affected

	Girls	Boys
Right sided	12	5
Left sided	38	17
Bilateral	17	10
	67	32 Total 99 pts.

RESULTS

After the infants could walk 97 had a clinical and radiographic examination One patient was examined at 7 months and one could not be traced All the infants walked at the normal time as a rule shortly before the age of 1 year

All those examined showed normal hip joints with free mobility without instability laxity or click except for one patient who still had a dry click Both legs were of the same length there was no muscular atrophy of the buttocks or thighs and walking was normal Radiologically all the hips were normal

DISCUSSION

Parkkulainen & Solonen (1959) assumed that the dry click was due to a flattened or oval sectioned ligamentum teres rotating under the femoral head in the Ortolani test They called the condition crepitation of ligamentous origin Barlow (1966) felt that fascial strands and tendons sliding over each other in the region of the greater trochanter were responsible According to Finlay et al (1967) the ligamentous click was due to the ligamentum teres and they emphasized that the click was so common that it must be considered within the range of normal In their opinion therefore the term click ought to be aban

doned so that the phenomenon should not be confused with Ortolani's click.

On the basis of our investigations it is not possible to decide whether the dry hip click is a sequel of congenital dislocation of the hip or merely a chance phenomenon in an otherwise normal hip. However, the distribution by sex and side affected supports the suspicion that it might be a sequel. This is indicated by the fact that expert examiners in our Department have found during the past 3–4 years 5 cases with congenital dislocation by the Ortolani test, whereas the test was negative a few days later when, after shedding the umbilicus, the patients were to be fitted with a plaster cast. Instead, the same examiner found merely a dry click.

In an editorial in *Ugeskrift for Læger* (March 1970) it was emphasized that in the event of the slightest suspicion of dislocation of the hip the patient should be placed in a plaster cast, as a few months' treatment in a cast is harmless even though 5–10 times too many are treated. Hiertonn & James (1968) have pointed out that a large part of the splinting is unnecessary, stating that for every child saved from frank dislocation they probably had fifteen to twenty others splinted. Fellander et al. (1968) did not splint 39 out of 82 infants with an Ortolani click, as this was demonstrable only on subluxation provocation; 5–7 years later all 39 children had normal hips.

Among 150 infants with hip dysplasia (acetabular angle greater than 30°) but without dislocation, Allen (1962) found following treatment by plaster cast in the Lorenz I position ischaemic necrosis of the femoral head in 14. Finlay et al. (1967) had no such cases but stressed that in the event of dry click, reduced abduction or laxity, splinting was unnecessary and caused the parents anxiety and concern.

Jansen & Reimann (1970), however, state that clinically doubtful cases with uncharacteristic sounds during the manoeuvres should be kept in a cast for 6 weeks as a matter of principle.

Our investigation has demonstrated that plaster casts in patients with dry hip clicks are unnecessary, as the hips become normal without treatment.

SUMMARY

Among 5060 newborns from a 2-year period, 17 were found to have dislocation of the hip and a positive Ortolani test, whereas 99 had atypical dry clicks. These latter 99 patients received no treatment and

the click had disappeared in 90 per cent at the end of 2 months The distribution by sex and side affected among these 99 infants was largely the same as in those with congenital dislocation of the hip

On clinical and radiographic examination of 98 of the patients at the age of 1 year when they could walk all hips were found to be normal

It is concluded that plaster casts in patients with dry hip clicks are unnecessary as the click disappears spontaneously and leaves the hip normal The infants should be followed by a specialist until the click has disappeared

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Departments of Orthopaedic Surgery and Clinical Physiology,
University Hospital, Umeå, Sweden

IMMEDIATE EFFECT OF OSTEOTOMY ON THE INTRAMEDULLARY PRESSURE OF THE FEMORAL HEAD AND NECK IN PATIENTS WITH DEGENERATIVE OSTEOARTHRITIS

Carl C. Arnoldi, Rudolf K. Lemperg & Håkan Linderholm

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Recently Arnoldi, Linderholm & Müssbichler (1971 and to be published) demonstrated a considerable hypertension in the cancellous bone marrow of the proximal part of the femur in patients with advanced stages of coxarthrosis. Simultaneous examinations by means of intraosseous phlebography indicated that the high pressure was accompanied by impaired venous drainage from the femoral head and neck.

There are indications that intramedullary hypertension may be a causative factor for the aching rest pains typical of these patients. Therefore we have thought it of interest to investigate the effect upon intramedullary pressure of two operative procedures routinely performed for painful conditions in osteoarthritis of the hip. In both procedures the medullary space is opened and drained: in osteotomy in the subtrochanteric region, in Smith-Petersen cup arthroplasty by removal of bone and cartilage from the femoral head.

In the present study the immediate effect of both procedures upon the intramedullary pressure was tested.

MATERIAL

Two groups of patients with degenerative osteoarthritis of the hip joint were examined.

The first group consisted of seven patients treated by means of intertrochanteric osteotomy. In the second group, containing eight patients, Smith-Petersen cup

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DISCUSSION

Immediate Effect of Osteotomy and Cortical Fenestration

Rest pain is often the dominant symptom of severe osteoarthritis of the hip joint. That high femoral osteotomy has a favourable effect on these pains has been noted by many authors (Osborne & Fahrni 1950, Pearson & Riddell 1962, Nissen 1963, Phillips, Bulmer, Hoyle & Davies 1967 and others). In ten of the eleven patients in the present study who complained of rest pains before the operation these pains had disappeared within 24 hours after the operation.

Recently Renard (1969) obtained equally satisfactory immediate relief of pain in patients with gonarthrosis by resection of altered subchondral tissue through a metaphyseal cortical window in the tibia and femur.

Although the effect of osteotomy and cortical fenestration is well known, the reason for the relief of pain is still a subject of discussion.

Intraosseous phlebography in patients with coxarthrosis has shown changes in the pattern of venous drainage from the proximal part of the femur. Normally the femoral head is drained through extraosseous veins in the joint capsule. As the osteoarthritic changes progress these peri-capsular extraosseous veins disappear from the phlebogram and the drainage takes place through dilated and tortuous intramedullary vessels into the femoral shaft (Mériel, Ruffié & Fournié 1955, Phillips 1966, Arnoldi, Linderholm & Mussbichler, to be published). Further, in osteoarthritis the venous outflow from the medullary space is greatly retarded (Arnoldi, Linderholm & Mussbichler, to be published).

Examination of the intraosseous pressure of the femoral neck showed that the changes in venous drainage were accompanied by an increase of pressure. There seemed to be a close correlation between rest pain and intramedullary pressure. Thus rest pains were never observed in patients with pressures below 35 mm Hg (intraosseous pressures from controls are given in Table 2), but were a constant symptom with intramedullary pressures above 40 mm Hg. In contrast, pain released by joint movements or loading seemed to be more or less independent of the pressure level (Arnoldi, Linderholm & Mussbichler, to be published).

Considered together, these observations seem to indicate that venous engorgement with stasis and intramedullary hypertension may be a probable cause of rest pain.

The results of the present investigation show that intertrochanteric

osteotomy of cortical fenestration of the femoral head result in an immediate and significant fall of the pathologically high pressure in the proximal part of the femur

The immediate decrease of pressure to normal or nearly normal levels would give a reasonable explanation of the often immediate disappearance of rest pains after these operations It also gives further support to the hypothesis that intraosseous hypertension may be the factor responsible for the rest pain in degenerative osteoarthritis

The intraosseous pressures obtained in the present study from patients operated upon for severe coxarthrosis are of the same order as those obtained from the femoral neck in hip joints with osteoarthritis by Arnoldi Linderholm & Mussbichler (to be published) In a series of patients with unilateral coxarthrosis they determined the pressures on the arthrotic and normal side simultaneously The collum pressures of controls in Table 2 are from the unaffected hip joints of that study The fact that these pressures were obtained with the patients in general anaesthesia lying supine on the operating table with the tip of the needle placed in the femoral neck probably permits a direct comparison with the pressures obtained from the patients of the present study In the controls the needles were introduced through skin punctures whereas a larger incision was used in the patients examined prior to operation However experiments have shown that intraosseous pressures are not influenced by surgical interventions in the surrounding soft tissue (as long as arterial supply and venous drainage to and from the bone are left intact) The slightly larger needles used for pressure measurements in controls according to our experience of pressure determinations give comparable results

The relief of symptoms obtained after intertrochanteric osteotomy has also been explained as the result of mechanical changes such as a medial shift of weight transmission (McMurray 1935 Pauwels 1959) correction of deformity (Malkin 1936) relaxation of the contracted capsule (Lloyd Roberts 1953) or elimination of tension in the psoas muscle (McFarland 1962) The main objection to these theories is the fact that osteotomy without displacement may give as good results as the displacement osteotomies performed by the spokesmen for the mechanical viewpoints (Nissen 1963)

Harrison Schajowicz & Trueta (1953) by means of injection studies on cadavers observed a hyperplasia of the intraosseous arteries of the femoral head in patients with coxarthrosis On the basis of these findings they assumed that the arterial inflow to the femoral head was in

creased. They concluded that the onset of pain was in some way dependent upon the degree of hyperemia. This conception was supported by Nissen (1963) who saw the effect of intertrochanteric osteotomy as a result of division of large medullary arteries. This would in his opinion cause a sharp and immediate reduction of the level of arterial hyperemia in the femoral head and neck.

The main objection to this hypothesis—which has not been supported by experimental evidence—is the fact that the femoral head receives most of its blood supply via the retinacular and intraosseous arteries deriving from the medial and lateral circumflex arteries. These vessels are situated proximal to the level of the intertrochanteric osteotomy. Interruption of arteries distal to these vessels can therefore only have a marginal effect upon an assumed arterial hyperemia of the femoral head.

Long Term Effects of Osteotomy

The present investigation clearly showed that one effect of osteotomy is an immediate fall of intramedullary pressure in the proximal part of the femur. If it is true as our observations indicate (see above) that the presence of rest pains is dependent upon the level of intraosseous hypertension, the often observed immediate relief of pain after osteotomy is easily understood. However, the osteotomy usually heals within a few months, whereas the effect of the operation may last for years. This lasting relief cannot be the result of drainage of fluids or a simple safety valve effect.

Phillips, Bulmer, Hoyle & Davies (1967) by means of intraosseous phlebography before and 12–20 months after displacement osteotomy observed that in most patients in whom osteotomy had brought relief from pain the venous drainage from the femoral head and neck had changed back to normal or nearly normal. Thus it seems that osteotomy may have an effect beyond the simple primary reduction of intramedullary pressure. How this is brought about is unknown at present just as we do not know the mechanism responsible for the initial failure of the drainage system from the femoral head.

SUMMARY

The intraosseous pressures of the femoral head and neck in patients with severe degenerative osteoarthritis were measured before and after incision or removal of cortical bone in the proximal part of the femur

Subtotal intertrochanteric osteotomy was performed in seven patients In eight patients in whom Smith Petersen cup arthroplasty was intended cartilage and subchondral bone was removed from the femoral head over an area measuring four by four cm

Prior to osteotomy or fenestration the intraosseous pressures of the femoral head and neck were high Both types of operation caused an immediate fall of pressure at both points of measurement

Intraosseous hypertension is a characteristic feature of degenerative osteoarthritis The immediate fall of pressure may be the factor causing the fairly constant and immediate relief of rest pains after osteotomy and Smith Petersen arthroplasty

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Surgical Department II Århus County Hospital Århus Denmark

FRACTURES OF THE TIBIAL CONDYLES

Ulf Lucht & Søren Pilgaard

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Fractures of the tibial condyles are characterized by the involvement of cancellous bone and weight bearing articular surfaces

The treatment of these fractures aims at obtaining a stable painless knee joint with good mobility

It is widely accepted that non weight bearing for a long time is needed but here the agreement ends and over the years there have been heated discussions as to whether operative or conservative treatment affords better results The advocates of operation (Bahr 1945 Fryjordet 1967, Jacobsen 1953 Palmer 1951 Rombold 1960) stress the importance of an adequate reduction in order to obtain good function and to avoid subsequent osteoarthritis Authors who support conservative treatment (Apley 1956 Poulsen & Tophøj 1969 Reibel & Wade 1962 Slee 1955) feel that in most cases operation is unnecessary Solonen (1963) concluded that the method of treatment had to be selected in each individual case

In a review on tibial condylar fractures Mortensen (1969) stated as a general rule that non displaced fractures and fractures showing a depression or displacement of less than 5 mm should be treated conservatively whereas operation should be considered in others

The reason why it has proved so difficult to arrive at an agreement in this important field is among others that tibial condylar fractures occur in many different types The various materials have been analysed according to different criteria and are therefore often not comparable There have not been reports on large prospective materials within which patients treated by conservative measures and by operation make up entirely comparable groups

In the present retrospective material operative as well as conservative methods have been used but it should be mentioned that the attitude in the Department is in favour of operation The object of this analysis was to relate the long term results to the therapeutic method

and thereby contribute to the discussion as to which method is preferable

MATERIAL AND METHOD

During the 10 year period 1959–1968 a total of 107 patients with 109 fractures of the tibial condyles were treated Two patients had bilateral fractures 69 fractures were left sided and 40 right sided

The material does not comprise fractures involving exclusively the intercondylar eminence

Before the treatment was decided upon the conventional X ray films were supplemented by tomography and on this basis the type of fracture and the degree of displacement if any were ascertained At follow up the history and clinical findings were supplemented by X rays anteroposterior views of both knees on long films and a lateral view of the fractured knee

Sex and Age

The age distribution and sex ratio are shown in Figure 1 55 were females and 52 males The majority were in the age range 40–80 average age 50 Within the individual age groups there was a male preponderance up to the age of 60 thereafter females predominated

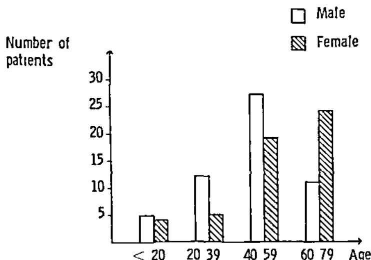


Figure 1 Age distribution and sex ratio

Table 1 Place of accident

		Number	%
Traffic			
Moped or motor bike	25		
Car (motorist)	18	69	65
Pedestrians	20		
Bicycle (cyclist)	6		
Home		24	22
Working place		10	9
Sport		4	4
		107	100

Our age distribution corresponds largely to that reported previously but several authors have had a male preponderance – Hohl & Luck (1956) for instance 444 males and 282 females

Place of Accident

Fractures of the tibial condyles occur as a result of direct injury to the outer or inner aspect of an extended or flexed knee or of indirect injury i e in the longitudinal direction of the leg It is not surprising therefore to learn from Table 1 that 65 per cent of the fractures were road accidents On the other hand it is remarkable that 22 per cent occurred at home and only 9 per cent during work or 4 per cent during games

This distribution is in fair conformity with that reported by Dovey & Heerfordt (1970)

Classification of Tibial Condylar Fractures

Like a number of others before us we felt that it was most expedient to use the classification of Hohl & Luck (1956) and Figure 2 illustrates the material thus classified

Fractures classified as undisplaced (28 per cent) involve the joint surface but may show a displacement of less than 3 mm on the X ray film The other displaced fractures comprise fractures with depression of the joint surface as well as fractures without depression The depression may be local or total *Local depression fractures may be sub*divided into fractures with a central depression (23 per cent) and split fractures with depression (17 per cent) Total depression fractures in

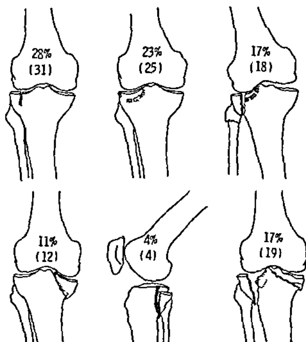


Figure 2 Classification by type of fracture

which the entire condyle is pressed down made up 11 per cent Split fractures which were displaced but not depressed made up 4 per cent Lastly there is a group of bicondylar fractures that may be more or less comminuted depression may be present This group which includes also pure "T fractures made up 17 per cent

This distribution of the fractures into the various types corresponds to that reported by Hohl (1967) In Dovey & Heerfordt s series (1970) more than one third of the fractures were of the split type with depression

In our material 79 fractures affected the lateral condyle 11 the medial condyle and 19 were bicondylar

Associated Fractures

At the time of the tibial condylar fracture 36 patients sustained 58 associated fractures 29 of the arms and the other leg The remaining 29 fractures affecting the same leg as the tibial condylar fracture are distributed as follows 3 of the femur 3 of the patella 5 of the tibial shaft 5 of the fibular shaft and 13 of the head or neck of the fibula

Table 2. Method of treatment

		Number	%
Operation			
Without bone transplantation	21	51	47
With bone transplantation	30		
Not operated			
Only non weight bearing	30	58	53
Only plaster bandage	26		
Reposition + plaster	1		
Extension followed by Plaster bandage	1		
		109	100

Method of Treatment

Table 2 gives the method of treatment. 51 or 47 per cent of the 109 fractures were treated by operation, whereas 58 or 53 per cent were treated conservatively.

In 30 operations bone grafting was done, the defects left by elevation of the joint surface being filled with a graft from the iliac bone fixed by cerclage or screw. In 21 cases the fracture was merely reduced and fixed by osteosynthesis material. After the operation 36 knees were placed in plaster casts. During the operation 13 semilunar cartilages were removed, whereas in others a detached semilunar cartilage was sutured. Secondarily two patients had a semilunar cartilage removed.

Among the conservatively treated cases 30 knees were treated merely by non weight bearing, while 28 were treated in plaster casts.

Table 3. Time for start of knee exercise and weight bearing

	Knee exercise	Weight bearing
≤ 4 weeks	51	10
5– 8 weeks	39	13
9–12 weeks	16	74
13–16 weeks	0	6
> 16 weeks	0	3
Not informed	3	3
	109	109

Table 4 Absent from work

	Number of patients
< 3 months	15
3– 6 months	48
7–12 months	7
13–24 months	2
Work not resumed	4
Unemployed before accident	16
	92

In the entire series then external fixation by plaster was used on 64 knees The cast was worn for less than four weeks in 11 cases from five to eight weeks in 38 cases and from nine to twelve weeks in 15 cases No patient wore a plaster cast for more than 12 weeks

The patients did exercises to train the knee (Table 3) In the majority of those who did not have plaster casts these exercises were instituted shortly after the accident while the others were started on exercises as soon as the cast had been removed The mean time of starting exercises was 4½ weeks after the accident

A relatively long period of non weight bearing was needed because of the characteristics of tibial condylar fractures (Table 3) Weight bearing was allowed on an average 12 weeks after the accident

Complications

Five patients developed paresis of the peroneal nerve transient in four Two of these patients also had fracture of the fibular head In five cases re operation was performed because of re displacement Two patients developed thrombophlebitis one after operation and the other one after conservative treatment Three patients had infection in the scar after the operation but none developed infective arthritis or osteomyelitis

FOLLOW UP

At the time of follow up 12 patients had died Three surviving patients were not seen as one could not be traced and two refused Thus the follow up material comprises 94 fractures of the tibial condyles in 92 patients or 94 fractures on 97 living knees (91 per cent) The follow

up period ranged from 18 months to 11 years averaging 5 years 8 months

Time Off Work

In analysing the time off work we also included housewives etc The majority (68 per cent) were disabled for less than 6 months (Table 4) This period depends *inter alia*, upon how heavy the work was the period being longer the heavier physical work the patient had

Four patients were obliged to give up their work completely This includes both patients with bilateral tibial condylar fractures Three patients had changed to lighter work after the accident

Jensenius et al (1961) reported that 58 per cent of their patients had returned to work within 6 months

Subjective Complaints

31 patients had pain on exertion as a rule only mild Only 9 patients had constant pain on exertion and 5 of them occasionally had pain at rest

Among other complaints it should be mentioned that 9 patients had restless knee due to weather changes 14 complained of instability 7 of restricted mobility and 16 had occasional swelling of the knee 10 patients had complaints of osteoarthritic nature

The complaints were distributed on 42 patients or 44 knees 20 treated conservatively and 24 by operation

Clinical Findings

In 7 knees there was an extension defect in 3 cases less than 5 in another 3 between 5 and 10 and in only one more than 10

The mobility was more than 120 in 85 knees while in five it was 90 120 and in four less than 90

There was lateral instability in five patients and distinct forward mobility in five

Out of the five patients with lateral instability four complained of instability and all of pain Out of the five patients with forward mobility one complained of instability and four of pain

Measurement of the thigh 10 cm proximal to the patella showed in 10 cases muscular wasting of 3 4 cm and in 21 cases of 1 2 cm

Table 5 Comparison of results of patients treated with operation and those treated conservatively

Fracture	Functional acceptable results as %	Anatomic acceptable results as %
Without depression		
Operated	88	63
Non operated	94	94
Depression 3–10 mm		
Operated	78	61
Non-operated	94	59
Depression > 10 mm		
Operated	79	58
Non operated		

Radiographic Findings

In one patient who was suffering from Lévi s syndrome the fracture was still very distinct and must be classified as ununited All the other fractures had united

In 24 patients there was still depression at the site of the fracture but often only a few mm 16 of these patients had been treated by operation

Valgus deformity was found in 22 patients of less than 5 in two patients and from 5 to 10 in 20 Two patients exhibited a varus deformity of 5 –10

Osteoarthritis was found in 39 knees but in 30 of these cases it was mild Halisteresis was observed in eight cases

Assessment of the Therapeutic Results

To sum up the results we felt that it must be expedient to use the classification of Hohl & Luck (1956) This classification is based upon an anatomic and a functional assessment the results being graded as excellent good fair and poor To simplify the classification we have combined the groups excellent and good as acceptable and the groups fair and poor as unacceptable The anatomical assessment includes the position of the fracture valgus deformity and degenerative articular changes if any The functional assessment includes mobility extension defect lateral instability strength working ability and pain

This classification shows that an acceptable functional result was

obtained for 82 knees (87 per cent) and an acceptable anatomical result for 67 (72 per cent)

To compare the conservatively and surgically treated fractures we divided the fractures by degree of depression (Table 5) However the groups are not entirely comparable as no regard was paid to an increase in width of the tibial condylar plateau

When considering the functional outcome we found better results in the conservative group if the fractures were non-depressed or only depressed 3-10 mm If the depression exceeds 10 mm we cannot tell as all such fractures were treated by operation As for the anatomical outcome the results were better after conservative treatment of non depressed fractures but if there was a depression of 3-10 mm the results were the same after conservative and operative treatment

To ascertain whether the time of instituting knee exercises influenced the results these two factors were plotted against each other A distinct difference was found to occur around the eighth week the functional result being acceptable in 90 per cent of the patients who had started knee exercise within eight weeks while it was acceptable in only 71 per cent of those who had started knee exercise later than eight weeks after the accident

Finally it should be mentioned that the result was somewhat poorer if the patients had associated fractures of the same leg The length of the follow up period was of no importance The results were no poorer in patients with over 5 years follow up than in patients followed for less than 5 years

DISCUSSION

The purpose of operating on patients with fractures of the tibial condyles must of course be to obtain results superior to those obtainable without operation In our material this was not attained in non depressed and slightly depressed fractures As already mentioned however we did not pay regard to a possible increase in width of the tibial condylar plateau in performing this classification For this reason the groups treated by operation and by conservative measures are probably not entirely comparable

Dovey & Heerfordt (1970) in a followed series of tibial condylar fractures had 36 per cent operated cases They found an acceptable functional result in 75 per cent and an acceptable anatomical result in 40 per cent This is somewhat poorer than in our series (87 and 72

per cent respectively) but the explanation is presumably that their material was selected comprising the most serious tibial condylar fractures transferred from other departments The same authors analysed the result by degree of depression In cases with fairly mild as well as more severe depression they found that operation meant no improvement of the functional result

Jensenius et al (1961) in a somewhat older material with an operation rate of 40 per cent found an acceptable functional result in 71 per cent and an acceptable anatomical result in 48 per cent These authors also found better functional results after conservative treatment in cases with fairly mild as well as with more marked depression

Poulsen & Tophoj (1969) analysing a series of 47 knees treated conservatively found an acceptable functional result in 85 per cent

Several authors (Apley 1956 Badgley & O Connor 1952 Poulsen & Tophoj 1969) use traction on the limb during the first weeks of conservative treatment

Apart from the problem operative *versus* conservative treatment the time of starting exercises also appears to influence the result In Rhesus monkeys Hohl & Luck (1956) demonstrated the importance of allowing mobility soon finding that it was thereby possible to avoid adhesions and to obtain a more favourable process of union with less synovial reaction The importance of early exercise has also been stressed by others (Reibel & Wade 1962 Roberts 1968 Weisman & Herold 1964) and our findings indicate the same

CONCLUSION

In the present material of tibial condylar fractures operation does not appear to afford advantages in cases of non depressed fractures and fractures in which the joint surface is less than 10 mm depressed All fractures with more marked depressions were treated by operation but according to recent literature some of these cases may also be treated conservatively Like previous authors we also found early exercises to be extremely beneficial

SUMMARY

In a surgical department 107 patients with 109 fractures of the tibial condyles were treated during a 10 year period The fractures have been classified and the material analysed according to the principles of



Figure 1 X ray view of forelegs of an adult rabbit two months after resection of an osteo periosteal segment of the radius No callus is seen

and an average weight 4 ± 0.25 kg These served as controls and were given no medication The second group consisted of twelve young rabbits with open radial epiphyses weighing 2 ± 0.2 kg each The third group consisted of twelve adult female rabbits similar to those of the first group They were treated with growth hormone after the bone resection Six animals were given bovine growth hormone distributed by the Endocrinology Study Section N I H Bethesda Md (NIH GH B 7 50 mg = 50 USP units) Each 100 mg of the dry bovine growth hormone powder was dissolved in 10 ml of saline and 1 ml NaOH 0.1 N was added Before injection this solution was diluted and each rabbit was given 4 mg of the hormone intramuscularly twice a week for three weeks thus receiving a total of 24 USP units Six other rabbits from the treated group were given porcine lyophilised somatotrophic hormone supplied by the Mann Research Laboratories (Division of Becton Dickinson & Co N Y) The solvent for the lyophilised hormone consisted of glucose 0.25 g phenol 0.025 g HCl and pH 4 and sterile water ad 5 ml Ten I U dry hormone were dissolved per ml and each rabbit was given 1 ml injections twice weekly for a month after operation thus receiving a total of 80 I U growth hormone

Rats

Thirty adult albino rats were used for histological studies A small 1 mm trephination hole was performed in both parietal regions symmetrically halfway between the auditory meatus and the sagital midline according to a technique we

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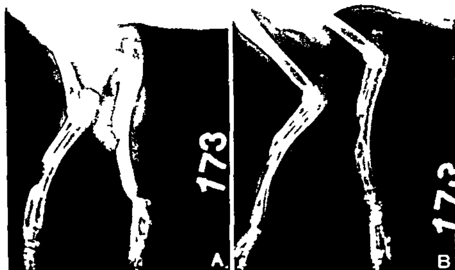


Figure 2 Forelegs of a young rabbit with open epiphyseal lines A) 1 month after resection of a radial segment new bon partially fills the gap B) Two months after operation the resected segment is practically replaced with new bone

used in a previous experiment (Herold Hurwitz & Tadmor 19/0) The operated rats were divided into two groups The first group consisted of eighteen rats which served as controls and were given no medication The second group consisted of twelve rats treated with growth hormone after the trephination of their calvaria They were given ovine growth hormone distributed by the Endocrinology Stud Section N I H., Bethesda Md (NIH GH S-5 Ovine) Each rat was given a one unit injection every other day receiving a total of eight units during the sixteen days following operation All the rats were killed seven weeks after operation and their cal aria decalcified with a solution of sod um citrate and formic acid in distilled water The specimens were embedded in paraffin cut in the sagittal plane and stained routinely with hematoxylin and eosin

RESULTS

Rabbits

The mortality among the operated animals left us with a reduced number at the completion of follow up four months after the bone resection Forty four radial bone defects among the adult controls

twenty among the young and twenty among the hormone treated rabbits could be evaluated as to their healing.

Table 1 shows the distribution of the bone defects according to the time required for the first appearance of callus on X rays. The difference between the adult animals on the one hand, whether hormone treated or not, and the young animals on the other hand is quite evident and statistically significant using the Chi square test ($\chi^2 = 21$, $p < 0.001$). Among the adult animals, though the appearance of callus seems at first view somewhat favoured by treatment with growth hormone, the difference with untreated controls is statistically insignificant ($\chi^2 = 1.3$, $p > 0.1$).

Table 1. Distribution of radial bone defects in rabbits according to the time required for the first appearance of callus on X rays

	Initial callus evident in four weeks	No callus whatsoever at four weeks	*Total no. of bone defects*
Adult controls	14	30	44
Young animals	19	1	20
Growth hormone treated adult rabbits	9	11	20
Total	42	42	84

Table 2. The incidence of non union in untreated adult rabbits, in young rabbits and in growth hormone treated adult rabbits

	Complete filling of bone defect by sixteen weeks	Non union with persistent bone defect	Total no. of bone defects
Adult controls	13	31	44
Young rabbits	18	2	20
Growth hormone treated adult rabbits	12	8	20
Total	43	41	84

Table 2 shows the incidence of non union in the three groups of rabbits. Here again the difference between the young and the adult animals is quite significant ($\chi^2 = 16.8$, $p < 0.001$). The difference between the hormone treated adult rabbits and untreated controls is statistically insignificant ($\chi^2 = 4.87$, $p > 0.05$).

Table 3 Histological findings in calvarial defects of growth hormone treated rats and of untreated controls seven weeks after operation

Histological aspect		Control animals	Growth hormone treated rats
Simple hematoma			1
Organised hematoma		11	5
Fibrotic callus		5	1
Osteoblastic reaction			
around bone defect	Weak	5	3
	Important	3	5
Total		24	15

Rats

The specimens of the drilled calvaria were examined under the microscope and the healing process evaluated seven weeks after operation The results of the histological examination are summarised in Table 3 For technical reasons several slides were unreadable so that fifteen bone defects in the growth hormone treated group and twenty four in the control group could be evaluated The findings varied between simple hematoma and more or less intensive osteoblastic reaction (Figure 3) When viewed by an objective observer not knowing which specimens represented growth hormone treated animals and which untreated controls no significant difference was found between the two groups

DISCUSSION

Koskinen (1963 1964 1967) has shown the effect of growth hormone and especially of its combination with thyreotropine on the formation of callus A treatment with the latter combination led to a larger callus and metabolic studies demonstrated a definite retention of calcium A clinical trial on humans gave the impression that the administration of growth hormone led to accelerated fracture union and favoured the healing of established non union In this last point the evidence is far from absolute since all cases had surgical treatment and the hormones were merely used as adjuvants

In a recent report Zadek et al (1961) describe a striking effect of growth hormone in preventing non union of long bone defects in the dog The series reported is very small and the present experiment was



Figure 3 Histological aspects of defects in rats' calvaria seven weeks after [illegible]
A) Untreated control. B) Growth hormone treated animal

an attempt to find whether similar results could be found in other animals

Hormonal treatment given in our series consisted of relatively large doses as compared to the experiments previously reported so that any pharmacological effect would be evident The influence on rabbits was far from clear and though a minimal acceleration of callus formation might be possible this was far from statistically insignificant

The histological study of rats calvaria with trephination defects showed no difference between growth hormone treated animals and untreated controls Such defects are never filled with cartilage and bone formation though minimal is by direct apposition in the hematoma Growth hormone on the other hand was shown to provoke hypertrophy of the cells of hyaline cartilage filling long bone defects The hypertrophic cartilaginous callus would act as a bone inducer Such a mechanism might expain why no influence of growth hormone could be found when studying the healing of calvarial trephination holes It might be concluded from the experiments described above that growth hormone has no effect on the healing of bone of membranous origin Its effect is limited to hypertrophy of fracture callus of long bones and an associated retention of calcium The acceleration of fracture healing previously reported in dogs was not evident in rabbits Further experimentation with growth hormone is necessary before its clinical use as adjuvant to fracture treatment is justified

SUMMARY

The effect of growth hormone on fracture healing was tried on long bone defects in adult rabbits and on calvarial defects of rats with intact pituitaries No statistically significant acceleration of healing was observed in either case In the light of previous favourable reports on the action of this hormone its failure in the present series might be due to the variation of animal species The lack of influence of growth hormone on the healing of skull defects could be explained by the hypothesis that its action is limited to bones of enchondral origin Further experimentation on the influence of growth hormone on bone healing seems mandatory before it can be recommended with certitude as an adjuvant in the treatment of fractures

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University Department of Pathology General Hospital Malmo Sweden

RECURRENT CHONDROMYXOID FIBROMA

PAWEL MIKULOWSKI & GÖREL OSTBERG

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During the last 30 years the number of known variants of cartilage forming tumours has considerably increased Chondromyxoid fibroma was described by Jaffe & Lichtenstein (1948) It is a rare tumour in large series of bone tumours it appears to constitute about 1 per cent (Dahlin 1956) Chondromyxoid fibroma is most common in the 2nd and 3rd decade of life but is very rare in childhood and after the 5th decade

The tumour has been described in various bones (such as os pubis scapula ribs vertebrae) but it is common in long bones and especially in the tibia In the long bones the tumour occurs in the region of the metaphysis but it may also involve the epiphysis The tumours are often fairly well defined in the roentgenogram They cause a swelling and rarefaction of the bone and break through the corticalis Chondromyxoid fibroma grows most often peripherally in the bone and may tend to involve adjacent soft tissues (Dahlin 1956 Iwata & Cooley 1958 Scaglietti & Stringa 1961 Verma et al 1967 present case) Chondromyxoid fibroma is regarded as nonmalignant but in at least 10 per cent of the published cases recurrences have occurred and transitions to chondrosarcoma have been described (Benedetti et al 1962 Iwata & Cooley 1958 Scaglietti & Stringa 1961)

REPORT OF CASE

A 42 year old man was admitted to the central hospital in Eskilstuna in 1949 because of a tender 10 cm by 7 cm bulging hard lump in the medial malleolus of the left tibia The patient reported that he had had the tumour for about 5 years Roentgenography showed destruction of the entire area of the medial malleolus and the corresponding part of the tibial metaphysis besides a marked thickening of the soft tissues with irregular cyst like formations with thin scales of cal



Figure 1 a Fontal view b Lateral view Roentgenograms taken Sept 1968 Defects after operations in distal tibia

deposits Operation revealed a tumour involving the bone as well as soft tissues It destroyed the tibial epiphysis and grew into the talocrural joint The exstirpated tumour was referred for microscopic examination About one month after the operation the wound was in good healing

Nineteen years later in January 1966 the patient was admitted to the Central Hospital Ängelholm He reported that for 10 years he had had a slowly growing lump in the upper part of the operation wound of the left lower leg Examination revealed a tangerine-sized lump which was adherent to the skin but not to the bone The lump was removed and sent for pathological examination Roentgen examination showed bone defects in the distal tibia as a result of the first operation (Figure 1 a b) (Roentgen films from 1949 were no longer available) At follow up in September 1968 and in November 1969 no further changes were seen

Histological examination at the first operation was done at Uppsala (Prof R Fåhreus PAD 1616/49) (Figure 2) The lesion was diag

Figure 2 Material from first operation in 1959 Characteristic tumour pattern Htx eos c a × 40

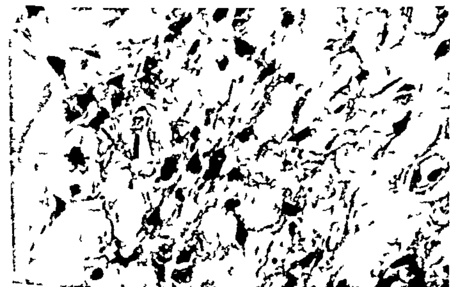


Figure 3 Material from second operation (1968) Loosely arranged pseudomalignant cells with polymorphous nuclei Htx eos c a × 400



Figure 4 Second operation Lobular extension into connective tissue Small fragments of atrophic bone peripherally Htx e s c a × 25

nosed as myxochondroma without definite signs of malignancy The recurrence 19 years later (Malmö PAD 1410/68) showed principally the same histology but the tissue appeared to be poorer in cells and to have more abundant intercellular substance The tumour showed a distinct lobular structure with crowded somewhat polymorphous pseudomalignant cells (Figure 3) peripherally in the lobuli and amorphous cartilaginous masses centrally The lobular pattern of the tumour was conspicuous especially in the periphery where it gave off several extensions into the connective tissue (Figure 4) No mature cartilage was seen The primary tumour as well as the recurrence contained extremely few giant cells Parts of the margin of the tumour contained some regular bone trabeculae probably residual fragments of corticalis

DISCUSSION

The case shows some features which may contribute to our knowledge of chondromyxoid fibroma The growth of large recurrent tumour in the soft tissues with at most minimal contact with bone has not

been reported before and is exceptional in a tumour primarily developing from bone It may suggest that the recurrence had developed from implantation of tumour remains in the operation area Rest of bone in the outer layers of the tumour may however suggest secondary separation of a large recurrence growing superficially in bone According to Dahlin (1956) recurrences are due to residual lobular extensions of the tumour and this explanation may also hold for single published cases of multifocal recurrences When recurrences occur they usually do so within 1–3 years of the first operation In one case a recurrence did not appear until 9 years after the operation (Kunkel 1955) It is difficult to date the recurrence in our case but the interval after the first operation seems to have been longer than in any other case on record

Chondromyxoid fibroma is classified as a benign tumour Increasing experience however suggests that the tumour is characterised by a fairly pronounced tendency to recur and to spread both in bone and in surrounding tissues In children below 10 years the tumour is very aggressive and it grows quickly and recurs very often (Scaglietti & Stringa 1961) As pointed out by Lichtenstein (1965) those 5 cases described by Scaglietti & Stringa (1961) as myxoma of bone in children should be classified as chondromyxoid fibroma We suggest that chondromyxoid fibroma be regarded as a tumour with a potential local malignancy

The relation between chondromyxoid fibroma and chondroblastoma has been discussed by Dahlin (1956) From a therapeutic and prognostic point of view it is most important to differentiate it from chondrosarcoma Both types of tumour occur in the same age groups though chondromyxoid fibroma appears in somewhat younger patients Owing to the histological appearance of pseudomalignant cells with irregular nuclei chondromyxoid fibroma can be easily confused with chondrosarcoma Most chondrosarcomas however contain fairly well differentiated cartilaginous structures with distinct lacunae containing atypical cells often with giant bizarre nuclei In the chondromyxoid fibroma the intercellular substance rarely shows lacunae with true cartilage cells The most important pattern of chondromyxoid fibroma however is lobular islands of ground substance with a condensation of polymorphous cells in the periphery of the islands and with streaks of loose metachromatic substance

SUMMARY

A 42 year old man sought advice because of a tender 10 cm long and 7 cm wide hard lump on the medial malleolus of the left tibia. The lump had grown during the last 5 years. Operation revealed a tumour of the bone with destruction of the tibial-epiphysis and involvement of the talo-crural joint. Nineteen years later the man was reoperated upon in the same area because of a recurrent lump which had been gradually growing for about 10 years in the upper part of the operation wound. The tumour grew in the soft tissues apparently without connection with bone. The histological picture was largely the same in both preparations and was compatible with a diagnosis of chondromyxoid fibroma.

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Martina Hansens Hospital Sandvika Norway

SPONDYLITIS PSORIATICA

NORVALD LANGELAND & ASBJØRN ROAAS

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The combination of psoriasis and peripheral arthritis is well known However psoriatic changes in the spine seem to be less familiar to many doctors Earlier these changes were often described as typical rheumatoid arthritis or spondylitis ankylopoietica These views have been opposed by several authors during the last years (Kaplan et al 1964 Bywaters & Dixon 1965 Jajic 1968) They assert that the patients with the skin disease psoriasis may have changes in their spine which are not similar to those seen in Bechterews disease or in rheumatoid arthritis The designation spondylitis psoriatica has been proposed for these specific changes

The patients described in this paper have been recorded in an orthopedic hospital during a few months in 1970 Some of the patients had no symptoms from peripheral joints All had suffered from back pain for several years The back pain started before the skin eruption in some patients whereas others got back pain later None began to have symptoms from the skin and the spine simultaneously This may be one reason why the true cause of the back pain often remains unrecognized for several years In our opinion this type of psoriatic disease is too little known For this reason we find it worthwhile to present these few cases

Case 1 S H J Fifty four year old man From the age of forty periods with pain in the middle of the back with several bad periods every year *At the age of fifty he got pain in several peripheral joints* and at the same time psoriasis pustulosa Three years ago X ray pictures showed destructive changes in the thoracic spine During the following years there was marked progression and the patient was admitted to our hospital There were no signs of infection neither clinical nor serological X ray examination three years ago (Figure 1) showed osteophytes especially in the middle of the thoracic spine



Figure 1 Case 1 Marked destructions of the corpora of Th VI and Th VII

Figure 2 Case 1 Solid fusion of the same vertebrae as mentioned in Figure 1

The inferior surface of Th VI and the superior of Th VII showed marked destruction Two years later the fusion of these two vertebrae started and upon admission there was a solid fusion (Figure 2) Further there seems to be some destruction of other thoracic vertebral surfaces In the lumbar spine there is only a tiny osteophyte on L V

Case 2 H M S Sixty year old woman with pains in her back and knees for several years and psoriasis pustulosa for one year Examina



Figure 3 Case 2 Prominent changes in the thoracic spine

tion revealed a marked kyphosis of the thoracic spine with poor mobility and with atrophy of the dorsal muscles X ray examinations show normal lumbar spine but in the thoracic spine (Figure 3) there are prominent osteophytes anteriorly on several vertebrae calcifications in some intervertebral spaces and lastly some sclerosis and tiny destructions in Th VI–VII and Th IX–X

Case 3 A P E Sixty year old woman with gradually progressing back pain for more than thirty years Shortly before hospitalization she got pain and swelling in her right knee and at the same time psoriasis pustulosa X ray examinations of her spine seventeen years ago showed tiny osteophytes anteriorly on some of the thoracic corpora Now we can see a marked progression and in addition there are some irregularities in the upper and lower surfaces of the vertebrae in the middle of the thoracic spine

Case 4 S M H Fifty year old woman with psoriatic exanthema since she was thirteen Ten years ago her exanthema was especially prominent and at the same time she got a lot of peripheral arthro-

pathies. She has suffered from back pain more or less continuously during the last thirty years. The present X-ray examination shows considerable osteophytes anteriorly and partly posteriorly on most of the thoracic vertebrae and in addition ligamental calcifications anteriorly between some vertebrae.

Case 5. B. B. Thirty-two-year-old woman with typical psoriatic exanthema and *progressing back pain during the last fifteen years*. X-ray examinations seven years ago showed osteophytes anteriorly on most of the thoracic vertebrae. These changes are now considerably more prominent.

DISCUSSION

In three of our patients X-ray examinations show a quite normal lumbar spine, whereas the other two have considerably less prominent changes *in the lumbar than in the thoracic spine. It is noticeable that* the changes are especially prominent in the thoracic spine, whereas the usual osteochondritis is localized preferably in the lumbar spine.

Some authors (Bywaters & Dixon 1965, Jajic 1968) have found osteophytes in the thoracolumbar spine especially often in psoriasis, but others (Graber-Duvernay 1957, Kaplan et al. 1964) describe the same changes preferably in the cervical spine. We have not examined the cervical spine systematically in our patients. Several authors (Sterne & Schneider 1953, Dixon & Lience 1961, Wright 1961, Lassus et al. *1964*) have also found changes in the sacro-iliac joints in psoriasis. Such changes do not exist in our material. In some reports (Schilling & Schacherl 1967, Jajic 1968) the spinal changes are often combined with peripheral joint affections. This is in agreement with our observations, because four of our five patients have revealed peripheral arthritis. One patient (Case 5) without peripheral arthritis showed comparatively modest spinal changes on the roentgenograms. Concerning psoriasis pustulosa it is said to be especially often combined with joint affections (Schilling & Schacherl 1967). This is also in conformity with our material as the three patients (Case 1, 2 and 3) with the most prominent spinal changes disclosed this type of skin affection. The diagnosis psoriasis pustulosa is in all three cases verified by dermatologists, as there is known to be other forms of pustulosis *where the pustules are not sterile as they are in psoriasis* (Andrews & Domonkos 1963). A septic process of the spine caused by spreading from a skin infection is therefore scarcely probable.

In our opinion Cases 1 and 2 had such special changes in their spines that they must be considered as true spondylitis psoriatica The X ray pictures in Case 1 show a slowly progressing destructive spondylitis during a period of fourteen years ending in a stage of solid fusion This kind of fusion seems to be quite unusual in spondylitis psoriatica but the psoriatic affection is the only reasonable explanation In Case 2 there are destructive changes like those seen in the earlier X ray pictures of Case 1 It may be of special interest in these two cases that there is localized destruction near the intervertebral spaces and mostly on both sides of the same space The theory may be put forward that the disease initially produces changes in the intervertebral space and secondly affects the vertebrae The final stage may be the solid fusion of vertebrae as seen in Case 1

SUMMARY

Five patients with spondylitis psoriatica are reported None got their back pain and exanthema simultaneously Four had peripheral joint affections three had psoriasis pustulosa The most prominent radiological changes were seen in the thoracic spine We pay special attention to the changes around the intervertebral spaces In one case there was fusion between two vertebrae

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Laboratory for Theory of Gymnastics University of Copenhagen
Universitetsparken 13 DK 2100 Copenhagen Ø Denmark

KINESIOLOGICAL COMMENTS ON SUBCUTANEOUS RUPTURES OF THE ACHILLES TENDON

TROELS BARFRED

On the basis of the history given by patients who have sustained subcutaneous rupture of the Achilles tendon Arner & Lindholm (1959) among others have described the type of the trauma (landing push off stumbling) but without further assessment of what happens in the individual muscles and joints or the forces which might be involved Nevertheless they concluded that an indirect injury would never be able to cause rupture in a healthy tendon Ljungqvist (1969) quoted Carlsöo who had reported that the stress on the Achilles tendon during fast running might reach 900 kp but did not state his opinion as to whether this might constitute an adequate trauma

Stucke (1950) found 400 kp to be the tensile strength of the human Achilles tendon In 1961 he believed that this limit may be exceeded in skiing accidents

Grafe in 1969 photographed the double backward somersault which is the situation in which rupture of the Achilles tendon is most apt to occur in gymnasts By measurements on the photographs he found that during the landing and the following push-off both Achilles tendons were exposed to a total stress of 1070 kp If unintentionally the somersault is asymmetrical the stress on one of the Achilles tendons would exceed $\frac{1070}{2}$ kp Grafe concluded that the stress was sufficient to cause rupture of a healthy tendon

Evaluation of the nature of the injury is based upon the history given by the patient As in other accidents or diseases these data may be inaccurate possibly misleading As far as tendon rupture is concerned the events take place in less than 1/10 second Very few people

The film sequence was kindly supplied by Laterna Film
The study was aided by a grant from Miss P A Brandt s Foundation

if any are able to give an accurate description of such a course of events Rasch & Burke (1963) report that when describing their own achievements top athletes often report movements and positions which cannot be found on control film sequences

Given the chance of analysing in more detail what happened at the moment of rupture one may get an entirely different impression of the course of events than that formed on the basis of the patient's description This applied when in the course of his work (filming) an actor sustained a right sided Achilles tendon rupture (Barfred 1966)

History The patient was a 35 year old male who had always been in good health and had not had any signs of disease in the Achilles tendon or calf He had previously trained in boxing riding football and fencing (not in competitions) but at the time of the accident he was out of training

Height 182 cm weight 78 kp

The patient stated that while filming he was running with a suit case weighing about 3 kp in his right hand He was wearing rubber soled shoes While he was running rapidly according to his physical condition at the time he suddenly felt pain in the right calf

When asked whether he had made an unusual movement just before he felt the pain he said no but stated that in the part he was acting he was to be provocative In the running scene he did this by heading straight for accidental pedestrians and then at the last moment stepping aside

He continued running with a slight limp but thereafter felt ill partly because of the exertion and partly because of the pain

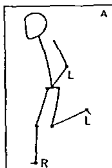
Together with the others in the cast he then relaxed over a glass of wine in the nearby studio He felt fit again had only slight tenderness in the calf and playfully made a few boxing steps

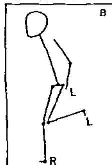
While doing so he collapsed with intense pain in the calf This happened about 2 hours after the first episode Three days later he underwent operation for right sided total Achilles tendon rupture Biopsy showed mild oedema but no definite degenerative changes

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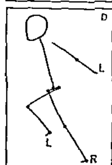
Figure 1 shows 4 consecutive photos (24 photos a second) taken from a car driving on a plane surfaced street beside the patient It will be noted that the patient has to proceed from the zebra crossing to the pavement

Each photo is accompanied by a rough sketch of the position of the legs and the left arm The partial rupture of the Achilles tendon is presumed to have arisen between A and C On D the right foot has left the ground



A
L
L
R


B
L
L
R


C
L
L
R


D
L
L
R

DISCUSSION

From the above it must be concluded that while filming the patient sustained partial rupture of the Achilles tendon which a few hours later became total

The film sequence (Figure 1) shows that the patient did not do just plain running After running for about 100 m he got to the curb which he had to ascend At the same time he had to step aside to the left of a lady who was just in front of him At this site the curb curved so that the patient had to make the step longer the more he had to draw aside to the left At this juncture he was supporting himself on his right leg and had to make his next step longer higher up and more to the left than in an ordinary running step

Kinesiological principles of measurement e g goniometry or electromyography presuppose preceding planning which of course was not possible in this case Instead the force used in the push off was calculated on the basis of the patient s weight and the acceleration in the push off The foot has then—according to Newton s 3rd law—been pressed against the ground with an equally great opposed force *In an attempt at lifting the heel from the ground—in the push off—* the ankle axis must be considered as the axis in the lever system The Achilles tendon would then be stressed by about 2 7 times this force as the distance from the ankle axis to the metatarsal heads is about 2 7 times greater than the distance from the ankle axis to the Achilles tendon (Haxton 1944 Gertsen 1956)

The upward movement was measured by the movement of the patient s ear in relation to the roof of the parked car The movement thus measured corresponds to the movement of the centre of gravity during running (Fenn 1930) The height of the ear (7 5 cm) was used as a yardstick The movement upward from A to B (L_{AB}) and from B to C (L_{BC}) lasted 1/24 second each The acceleration (a) may then be calculated according to the formula

$$a = \frac{L_{BC} - L_{AB}}{1/24 \times 1/24} \text{ cm/sec}^2$$

The force was found as the product of mass and acceleration As the mean of repeated measurements the force was found to be 164 kp

In this early phase of the push off the calf muscles would meet a *resistance of 164 × 2 7 kp = 442 8 kp* A similar calculation on an ordinary running step shortly before the accident showed a force of

78 kp and thus a resistance of 202 8 kp against a possible contraction of the calf muscles

To assess whether the force demonstrated would be able to damage the Achilles tendon it is necessary further to consider (1) the possibility of elongation and thereby also the direction of traction on the muscle tendon group (2) the muscle force in the triceps surae muscle and (3) the muscle function and innervation pattern

1 *Elongation and Direction of Traction*

Owing to extension in the knee and dorsal flexion in the ankle the muscle tendon group would be elongated Whether this strain was sufficient to produce tendon rupture cannot be decided partly because in this case we do not know the extent of the movements in the knee and ankle joints and partly because we do not know the strain required in man to exceed the rupture limit

Statements of the force of an Achilles tendon as 5–10 kp/mm (Cronkite 1936) or 400 kg (Stucke 1950) presuppose that the tendon is strained in the longitudinal direction This was probably not so in our case as the sideward movement must have caused some supination of the calcaneus

At a supination of 30 straining of 10 per cent and a 1 5 cm width of the Achilles tendon the author has calculated that the lateral fibres have reached the 10 per cent strain at the time when straining of the medial fibres begins Such a calculation means a considerable simplification as it presupposes that the tendon is homogeneous However it is made up of interfibrillar substance and of fibres which are rotated and crossed with interdigitation between parts of the fibres All this presumably tends to abolish the unfavourable effect of the supination (Mollier 1937 Altmann 1963) The corrected calculation cannot be carried out as there are too many unknown factors but it is unlikely that the effect of supination could be entirely abolished In experiments not yet published the author has found a tendency to a greater frequency of experimental tendon rupture caused by oblique than by straight traction Even with straight traction on the tendon i e with the calcaneus in the mid position there is a possibility that the architecture of the tendon may prove unfavourable Christensen (1954) feels that the rotation which Cummins et al (1946) have described may cause a saw like damage to one part of the tendon (gastrocnemius) by the other part (soleus)

knee and about 2 cm with flexed knee (Bugnion 1892) In other words the triceps surae may be affected by a force of 666–1000 kp

Thus without forces external to the body an incoordinated innervation may be sufficient to exceed the tensile strength of the Achilles tendon

CONCLUSION AND SUMMARY

The author reports a case of subcutaneous Achilles tendon rupture in which the patient, at the time of the accident was acting the part of a provocative restless character He had a sudden motive for altering the direction of this movement and thereby the innervation of his muscles has possibly been incoordinated During a push off he achieved a force of 164 kp, a force which has been able to stress the triceps surae by 443 kp Presumably he could have produced an isometric force of 289 kp in the triceps surae a tension which by eccentric contraction might be increased to 435 kp He made a movement which strained the triceps surae muscle and tendon During the push off he had a more or less supinated hindfoot Whether he innervated the triceps surae at an unfortunate moment is not known It is also not known whether the strain of the muscle tendon group has been great enough to induce rupture However the possibilities for rupture were present although the patient said that he only came running This is by no means a proof that the tendon rupture occurred on a traumatic basis in a healthy tendon But it emphasizes that there are possibilities of extremely great forces acting in the human body—also without external influence At the same time it emphasizes that a patient s statement that no trauma has occurred in connection with a tendon rupture ought to be regarded with considerable skepticism

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Laboratory for Theory of Gymnastics, University of Copenhagen,
Universitetsparken 13, DK 2100 Copenhagen Ø, Denmark

EXPERIMENTAL RUPTURE OF THE ACHILLES TENDON

Comparison of Experimental Ruptures in Rats of Different Ages and Living Under Different Conditions

TROELS BARFRED

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Sallefranque in 1887 performed a minor series of experimental ruptures on a dog anesthetized with ether. He subjected the intact bone-muscle-tendon-bone chain, *inter alia* the biceps brachii and the triceps surae, to stress with simultaneous electrical stimulation of the muscle. The result was avulsion of bone, muscle rupture, and, after the dog had died, a tendon rupture in the left biceps brachii.

Lindblom (1939), in experiments on a fraction of the supraspinatus tendon on cadavers, obtained tendon rupture in a couple of cases. He mentioned the significance of loading the tendon with the humerus abducted, which strains the articular part of the tendon first.

In all other studies of bone-muscle-tendon-bone chains it has proved impossible to induce tendon rupture. McMaster's study from 1933 on young rabbits is most often cited. He concluded that a healthy tendon never fails as a result of indirect violence. His method was not above criticism. He did not stimulate the muscle, and he applied traction on the foot so that its long axis was in continuation of the tendon. These drawbacks were corrected by Fink & Wyss (1942) and by Davidsson (1956) without, however, altering McMaster's conclusion.

None of these authors paid regard to the animals' age and fitness, although it is stated concurrently that rupture of the Achilles tendon occurs predominantly in men aged 30–50 who are or have been athletic (Arner & Lindholm 1959, Picaud et al. 1966, Frings 1969).

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Vudik (1969) trained rabbits towards the end of their growth period Subsequent experiments did not induce tendon rupture but mainly avulsion of bone from the calcaneus This worker did not use stimulation of the muscle

In the present study the author investigated wild and domesticated rats to compare animals living under different conditions A later study (Barfred 1971 b) was concerned with the effect of the various types of stress to which the bone muscle tendon group may be exposed

MATERIAL AND METHOD

All the rats were of the Norway strain some being albino and others wild brown rats These two types are so closely related that they mate mutually (Donaldson 1924 Richter 1954)

Table 1 gives the sex and weight distribution of the wild rats which had been captured less than two weeks before the experiment Male rats more than 300 g and female rats more than 250 g made up the control group against other large rats whose conditions of living were different

Table 1 Distribution of albino rats and of recently captured wild brown rats The framed figures represent the control group

Conditions of living		No of investigated legs			
Group		50–150 g	150–250 g	250–300 g	> 300 g
Domesticated	♂	10	10	0	10
Domesticated	♀	0	0	[illegible]	8
Wild	♂	10	10	12	13
Wild	♀	12	17	14	15

Table 2 Distribution by weight sex and conditions of living of the large rats In addition mean body weight

Conditions of living			No of investigated legs		
Group	Average weight g	Total	♂ > 300 g	♀ 250–300 g	♀ > 300 g
Domesticated	386	20	10	[illegible]	8
Kept in run	375	[illegible]	8	[illegible]	[illegible]
Wild	338	42	13	14	15
Inactive	357	14	8	4	-



Figure 1 Testing machine On the right the condylar clamp (Figure 4) which may be adjusted to infinite variability by means of the large cogwheel On the left the calcaneal clamp (Figure 4) the ball bearing suspension and revolving potentiometer (Figure 2) the steel ring by which the alterations in tension are measured and on the extreme left the handle by which the calcaneal clamp may be pulled manually away from the condylar clamp

Table 2 gives the weight and sex distribution in the 4 groups of large rats living under different conditions One group of rats had been kept in a room 4 × 3 5 m since birth These rats hereafter called run kept rats were the first or second generation of wild brown rats The inactivity group consisted of brown rats kept after their capture in a cage 30 × 40 cm The experiment was performed 3-3½ months after the capture

For the study of the bone muscle tendon bone organ the anaesthetized rat was fastened in a material testing machine (Figure 1) The anaesthesia was effected by pentobarbitone sodium (Nembutal®) 5 mg/100 g body weight intraperitoneally For the wild rats the anaesthesia had to be induced by ether Thereafter half the dose of Nembutal could be administered The other half was given when the ether had been eliminated With the following experimental procedure Nembutal cannot be expected to have exerted any major influence upon the contraction level of the muscle (Secher 1951 Kraatz et al 1953 Sirnes 1954)

Stimulation was performed by exposing the sciatic nerve through an incision on the lateral aspect of the thigh. By dividing the muscle easy access to a 2-3 cm segment of the nerve was gained The nerve was embedded in a piece of split rubber tube Inside this tube a double electrode was placed and connected to the stimulator (Disa Multistim) Stimulation was performed by train of square wave pulses 40-60/sec amplitude 1 v duration 0 7 msec In preliminary experiments it was attempted to place the nerve outside the rubber cuff while the electrode was inside Stimulation hereafter often failed to induce contraction of the triceps surae or caused only a weak contraction Thus despite the short distance from the electrode to the muscle there was but little direct stimulation

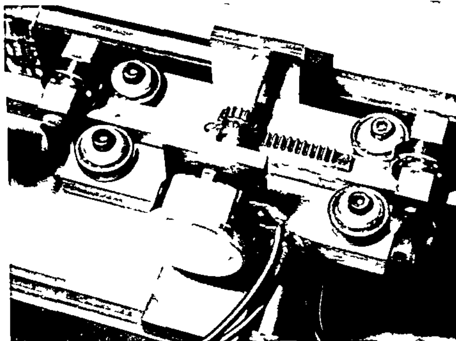


Figure Ball bearing suspension of the rod on which the calcaneal clamp is placed The rack operates the cogwheel which is coupled to a revolving potentiometer by which the movements of the calcaneal clamp are recorded

The material testing machine consisted of a strong frame at one end of which a condylar clamp was fixed to a rod which could be adjusted in an infinitely variable way to the desired length. At the other end of the frame a calcaneal clamp was fixed to a rod which by a handle could be pulled 95 mm away from the condylar clamp This elongation always entailed rupture somewhere The movement was recorded by means of a rack operating a cog wheel placed on a revolving potentiometer (Figure 2)

The tension between the calcaneal clamp and condylar clamp was recorded by deformation of an inserted open steel ring Between this ring and the calcaneal clamp the rod was suspended in 4 sets of ball bearings (Figure 2) so that the movement occurred with a minimum of friction and so that only the forces acting in the longitudinal direction of the rod were measured

The deformation of the steel ring was measured by a strain gauge connected to a Philips measuring bridge The results of the tension variations and the elongation were recorded simultaneously on a Honeywell visicorder At a calibration within the measuring range used the tension and elongation curves were linear On each experimental day the tension recordings were calibrated before and after the experimental series using a load of 10 kg Thus the loading could be determined with an accuracy of 0 2 kg and the elongation with an accuracy of 0 5 mm

Figure 3 Top The drill for piercing the calcaneus and condyle Bottom left The plate whose notch fits the calcaneus The pin is to be passed through the calcaneus The plate turns on an axis just beside the notch Bottom right Clamp for the femoral condyles with the pin which is to be passed through the condyles

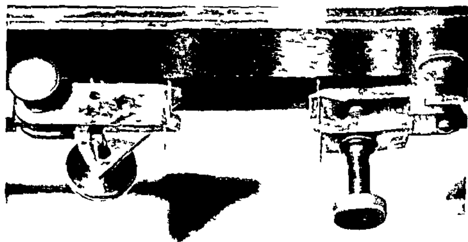


Figure 4 Calcaneal clamp and condylar clamp as placed in the testing machine seen obliquely from above

The calcaneus was exposed by a "stirrup" incision which on one side reached a little higher than the muscle tendon junction The plantaris tendon—which in the rat passes behind the calcaneus to the sole—was resected The calcaneus was fixed to a 2.5 mm thick metal plate (Figures 3 and 4) with a notch shaped like the bone (3 different plates were used with different sized notches) At right angles to the notch a hole was drilled through the plate and calcaneus by an inserted pin the calcaneus could be fixed to the plate The plate could be turned 30° on an axis at right angles to the leg in the sagittal plane just above and beside the calcaneus This induced on the right leg a pronation movement and on the left leg supination The plate was further provided with an angle bar to keep the foot in a right angled position

The condylar clamp (Figures 3 and 4) was made according to the same principle as the calcaneal fixation but instead of a fixed notch there was an adjustable clamp which could grasp the bone The needle was placed through the bone at the knee axis The thigh was tied to the apparatus to secure a rigid position of approximately 40° flexion in the knee joint

The lower leg was cut just above the ankle so that the Achilles tendon was the only connection between the knee and the foot The bone tendon muscle bone group could then be elongated until rupture occurred in one of the named structures

When the rat was placed in the machine the calcaneal clamp was placed in zero position (the position from which a 25 mm elongation was possible) and the condylar traction was adjusted to and fixed in the position which rendered possible the named articular positions (90° flexion in the ankle and approx 40° flexion in the knee)

All the rats were weighed with an accuracy of 5 g their sex was determined and the females were investigated for pregnancy *Foot length* (distance from heel to longest toe) and *muscle tendon length* (distance from muscle origin to tendon insertion)—at maximum dorsal flexion of the ankle/extension of the knee joint at 90° flexion of these joints and at maximum plantar flexion of the ankle/maximum flexion of the knee—were measured with a vernier caliper with an accuracy of 0.5 mm *Muscle tendon length* is taken to signify the length at maximum plantar flexion in the ankle joint and extension of the knee

Excursion signifies the difference between the greatest and shortest length of the muscle tendon group

After the rat had been fastened the *muscle force* was measured during tetanic stimulation Thereafter the loading experiment proper could be carried out

Elongation of the bone muscle tendon bone group was always done manually Thereby it was possible to carry out an accelerating movement corresponding to natural movements

The loading experiments were always done with simultaneous tetanic stimulation of the muscle 30° angulation of the footplate and rapid elongation of the muscle tendon group (average 250 per cent of the muscle tendon length per sec)

The *initial length* is the length of the muscle tendon group when the foot is in a rectangular position and the knee flexed 30–45° In numerous experiments this corresponded accurately to the elastic equilibrium length (the greatest length of the relaxed muscle without application of external force) In the large rats this length was about 2 mm shorter than the muscle tendon length as defined above

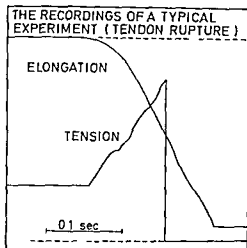


Figure 5 Typical recordings in a rupture experiment Read from left to right Top curve (descending) represents the elongation The horizontal segment of the bottom curve represents the muscle force in isometric contraction induced by tetanic stimulation The remainder of this curve illustrates the increase in tension until rupture

Figure 5 gives a typical curve illustrating a rupture experiment The descending curve indicates the elongation whereas the ascending one indicates the increase in tension The graph paper moved at a fixed speed and it will be seen that at the outset the elongation was performed with a greatly accelerating movement and towards the end at an even speed The increase in tension was irregular there being flattenings of the curve the first one at an increase in tension in relation to the maximum isometric tension of about 50 per cent In addition to these more horizontal parts of the curve there were sharper irregularities—occasionally with a slight fall of tension These dips must be interpreted as partial interruptions of continuity (cf Viidik 1966)

On the curve the author measured the *separation force* signifying the tension at rupture *Elongation* signifies elongation at rupture Moreover the elongation at an increase in tension up to 1 5 2 0 2 5 and 3 times the maximum isometric force was measured on the curves Thus $L_{2\,0}$ is the elongation at an increase in tension up to twice the isometric force $\Delta L_{1\,5}$ the elongation from $L_{1\,5}$ to $L_{2\,0}$ affords an impression of the inclination of the steep part of the length tension diagram

Statistical Method

All data were entered on paper tapes and the material was analysed on a GIER computer

Unless otherwise stated the linear regression equations were determined for the named parameters and compared between the groups In comparing the distribution of the site of rupture in the various groups the approximate χ^2 test was used

Differences were considered significant when $p < 5$ per cent

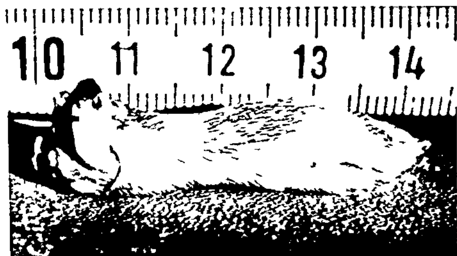


Figure 6 Rat foot after rupture experiment resulting in tendon rupture Note the tendon end on the left Only a small part of the lower leg is visible As stated in the text it was cut before the rupture experiment

RESULTS

Site of Rupture

The rupture experiments had one of the following results

1 Fixation ruptures where the rupture occurred at the site of the inserted pin either in the calcaneus or in the femoral condyles

2 Tendon ruptures where the rupture occurred in the tendon proper Frequently the site of rupture was close to the insertion but just as often 1–2 mm from the tendon insertion The ruptures were often oblique in that case the tendon remnant on the calcaneus might be 3–4 mm in length on one side (Figure 6) The oblique course of the separation line bore no relation to the lateral or medial side of the tendon or to whether there was a question of a supination or pronation trauma

3 Muscle rupture where the rupture was localized to the muscle as a rule at the transition between its middle and lower thirds

4 Other ruptures which might be combined muscle tendon ruptures or muscle or tendon ruptures with avulsion of a fragment of bone from the condyle or the calcaneus

Figure 7 gives the distribution of ruptures in the wild brown newly captured rats The tendon ruptures occurred only in the heavy weight groups The weight above which tendon ruptures occurred was about

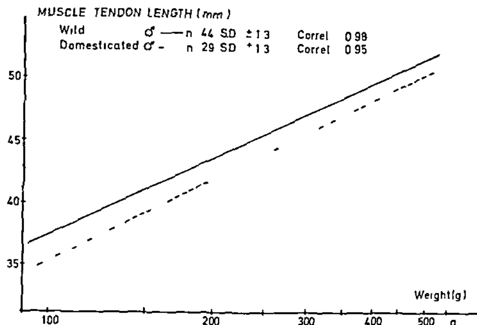


Figure 9 Correlation between muscle tendon length and body weight Weight scale logarithmic The lines represent the regression equations for domesticated rats and for recently captured wild rats Force unit Kp = 9 81 × 10⁵ g cm/sec = 9 81 N (Newton)

Among females weighing more than 300 g 4 were pregnant Among 5 investigated legs 2 tendon ruptures occurred

Foot Length Muscle tendon Length, and Excursion

The length of the foot and the muscle tendon group was found to be rapidly increasing for the small rats the growth rate decreasing in the large rats

The relationship between the muscle tendon length and the log weight may reasonably be described as a linear function (Figure 9) *The length of the muscle tendon group was significantly greater in* the wild than in the domesticated rats and greater in males than in females The muscle tendon length log weight relation also showed that the muscle tendon length at the same weight in the inactivity group and in the run kept group was greater than in the control group

The longitudinal growth of the foot appears to decrease at a lower weight than does the longitudinal growth of the muscle tendon unit

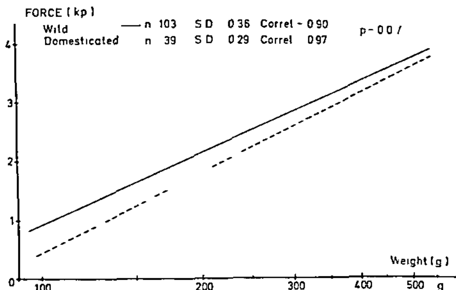


Figure 10 Correlation between muscle for e and body weight of domesticated rats and recently captured wild rats The lines represent the respective regression equations Weight scale logarithmic

The foot length log weight relation cannot be considered a linear function Foot length was shorter in domesticated than in wild rats and shorter in females than in males

Otherwise foot length did not exhibit any major relationship to the basic parameters (muscle force muscle tendon length and body weight) in the different groups The same applied to the excursion whereas a comparison of foot length with excursion showed a reason able relationship This relationship was the same for all groups except the one from the runs which showed a greater excursion at the same foot length than the other groups (p = 0 7 per cent)

Muscle Force

In most groups the force was about 10 times greater than the body weight This force weight relation decreased with age so that the relationship between force and log weight may be reasonably described as linear (Figure 10) without this form of comparison being inter pretable as a biological law

There was no sex difference in the force log weight relationship Considered together the wild rats were stronger than the domesticated

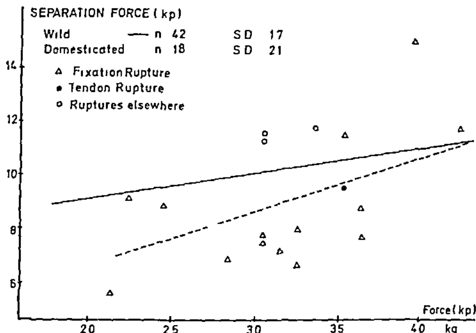


Figure 11 Correlation between separation force and muscle force of large domesticated rats and large recently captured wild rats The lines represent the respective regression equations The position of the individual rupture experiments is marked only for large domesticated rats by symbols a cording to the site of rupture These marks form the basis of the broken line

rats of the same weight (Figure 10) but if only the large rats were compared there was merely a tendency to greater force in the wild rats (p = 10 per cent) The inactivity group exhibited no difference from the control group but the run kept group showed a tendency to greater force

Comparison of the force muscle tendon length relationship between the different groups showed a very stable relationship except that the pregnant rats were found to be a little weaker at the same muscle tendon length Pregnancy appears to involve weakening of the muscles

Separation Force

The absolute separation force was in the order of magnitude 3 times the muscle force and about 30 times the body weight

The separation force muscle force relationship was almost linear but with a distinct tendency to flatten off in the largest rats (Figure 1 Barfred 1971 b)

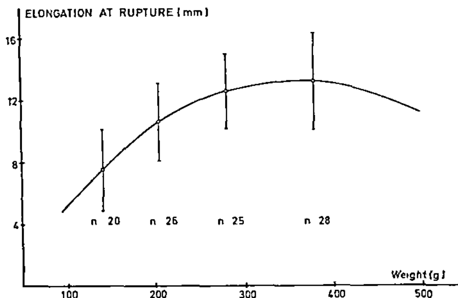


Figure 12 Elongation at rupture Standard deviation given for 4 groups 50–150 g 150–2 0 g 250–300 g and > 300 g but the curve was drawn on the basis of all the marks

In relation to log weight there was no difference between the control group and the inactivity or run kept group but in relation to muscle force there was a tendency to a lower separation force in the run kept rats and a significantly lower separation force in the inactivity group There was no difference in these relationships between males and females

In relation to muscle force as well as log weight the separation force was significantly greater in wild than in domesticated rats

Figure 11 illustrates the position of the individual experiments on large albino rats in a muscle force-separation force diagram The separation force was in one third of the cases above the regression line for the wild rats In 3 of these 6 cases rupture occurred outside the fixation sites The only tendon rupture in this group occurred at a separation force which was below the regression line for the albino group

Elongation

The elongation was about 25 per cent of the muscle tendon length The elongation had been carried out at a rate of about 250 per cent/sec

The elongation weight relationship increased up to a body weight of 300–350 g, whereupon it decreased (Figure 12)

Between wild males and females there was no difference in the elongation-weight relationship whereas elongation at the same weight was significantly lesser in domesticated than in wild rats The "run kept rats behaved like the wild rats whereas in the inactivity group the elongation was significantly less marked

The relationship between elongation and muscle tendon length was the same in domesticated as in wild rats with the same tendency to a decrease at high muscle tendon length as well as at high weights (cf Figure 12) Between the wild rats and the "run kept rats there was no difference but the elongation at the same muscle tendon length was significantly lower in the inactivity group

The separation force elongation relationship may reasonably be described as linear The drop or flattening of the elongation seen at high weights and at great muscle-tendon lengths was not found at high separation forces The separation force-elongation relationship showed that the separation limit was reached at a lesser elongation in the inactivity group and in the "run kept group whereas no difference was observed between wild and domesticated rats

L_{20} in relation to muscle tendon length or log weight showed no difference between the groups

Δl_{15} was significantly lower for domesticated than for wild rats corresponding to greater rigidity in this part of the length tension diagram

Direct comparison of the above mentioned parameters between the inactivity and run kept groups showed that the groups were to a marked extent similar However a very essential difference was found in the frequency of tendon ruptures which was significantly higher among the inactivity rats The only other difference found was in the separation force muscle force relationship which showed that the regression line was steeper for run kept than for inactivity rats ($p = 4.7$ per cent) If it is assumed that the lines nevertheless have the same inclination further analysis shows the lines to be identical

Supplementary Experiments

In all the above experiments the layers of skin and fascia overlying the muscle were intact. This might have stabilized the muscle so much in relation to the entirely exposed tendon that the rupture pattern might be displaced in favour of the tendon This might perhaps have been the factor which rendered it pos

sible at all to induce tendon rupture For this reason a few experiments were performed on large wild rats in which the muscle too was exposed by the incision In 3 such experiments 1 muscle rupture and 2 tendon ruptures occurred

In addition a series of 10 experiments was performed with a straight traction on the calcaneus of large domesticated rats i e without supination or pronation Tendon ruptures might have been masked when an oblique traction was applied to a weak bone However in this group also only one tendon rupture occurred

DISCUSSION

The Achilles tendon in the rat is 1–1 5 cm in length made up like all tendon tissue of densely arranged collagen fibres interspersed by slender fibrocytes Close to the insertion the fibrocytes get to resemble chondrocytes ever more being gradually arranged in columns so that the distance between the fibres widens There are no signs that this reduces the total cross sectional area of the tendon fibres (Cooper & Misol 1970) Close to the junction to the bone there is a saline track forming the demarcation between the juxta insertional part in which there is precipitation of calcium salts and the free part of the tendon which as a rule contains no calcium salts

In histological examinations of the proximal tendon stump performed in all cases of tendon rupture this track of saline was decisive in ascertaining whether the rupture was interpreted as a tendon rupture or—if the track of saline was present—as a tendon rupture with a bone fragment In nearly all cases the fragment of bone attaching to the tendon stump was clearly visible on gross inspection and it was only in one case that histological examination was needed to make this decision

The explanation why in the present study the rupture site was 0–2 mm from the calcaneus and not as in man 2–6 cm from the insertion of the 10–15 cm long Achilles tendon may quite possibly be the difference found in the architecture of the tendons (cf Barfred 1971 b) It was reasonable therefore that ruptures showing tendon tissue proximally as well as distally to the rupture site were interpreted as tendon ruptures

Davidsson (1956) did not accurately describe the ruptures which he called insertion ruptures but according to the above criteria some of them would presumably have been classified as tendon ruptures

Many workers (Davidsson 1956 Arner & Lindholm 1959 Lang & Wernstein 1966 Konn & Everth 1967) have considered degeneration to be the main cause of tendon ruptures In the present experimental

series histological studies did not reveal any degeneration at the rupture site (Barfred 1971 a)

The failure of previous authors to induce tendon rupture of healthy uninjured tendon may have been due to an erroneous procedure

McMaster (1933) strapped the calcaneus in a way so that the long axis of this bone was in continuation of the tendon and this unnecessarily attenuated the bone at the site of insertion He also did not use stimulation of the muscle But the most important factor of all was probably that no regard was paid to age or conditions of living in selecting the experimental animals Viidik (1968 1969) tried to remedy this by training the experimental animals but nevertheless did not succeed in inducing tendon ruptures He trained 3 month old rabbits in running through 40 weeks The rabbits ran about ½ km every day This does not seem much compared with the distance that a wild animal covers in 24 hours although the speed in the training was as high as possible Slonaker (1912) found that domesticated albino rats in a revolving cage moved spontaneously from 2 to 5 miles a day

It is questionable whether such one sided training of young animals can be compared to wild animals in regard to separation force in bone tendon and muscle and in regard to maximal isometric muscle force Ingelmark (1945) reported that by training young animals increased their muscle weight as well as tendon weight whereas older animals increased mainly their muscle weight It has been emphasized by Elliott (1965) and by Elliott & Crawford (1965) that the cross section of the tendon is determined by the total tension to which the tendon is exposed in the course of time not by the contraction force of the appurtenant muscle

To increase the muscle force training has to be severe meaning that it must be performed with more than 50 per cent of the maximum isometric force (Bonde Petersen 1960 Hettinger 1964) In rats Saville & Smith (1966) and Smith & Saville (1966) have studied the effect of increased demands on the hind legs cuased by early amputation of the forelegs Apart from an increased specific gravity of the femur a greater separation force and an increased Ca content they found the mass of muscle on the hind leg to be increased By intense training of the plantaris muscle (after cutting the Achilles tendon of rats) van Linge (1962) found that the muscle underwent violent hypertrophy At the same time he noticed a marked increase in the connective tissue of the muscle However this latter finding was not studied in any detail neither quantitatively nor qualitatively

On the basis of the above studies it is not possible to set up any definite laws applying to the development of muscles tendons bones—at any rate not to the extent that it is possible to evaluate effect of a running exercise programme and even less that of increased physical activity which may be expected to be found in a wild animal as compared with a domesticated one

There is also the difference relating to the food not only qualitative and quantitative but also the difference in the rhythm with which food is taken and perhaps also in the environmental temperature Chvapil (1967) in particular has studied the influence of [illegible] tors upon connective tissue He found domesticated rat [illegible] quickly than wild rats and the process of ageing to decrease [illegible] mittent *versus* free intake of food Physical training [illegible] calcium/hydroxyproline ratio and an increased content [illegible] proline in the bones a difference also found between [illegible] wild and domesticated rats (Chvapil & Roth 1964) [illegible] the view of Donaldson (1924) who claimed that nearly [illegible] between wild and domesticated rats were caused [illegible] living This deduction was based upon training of [illegible] as well as taming of wild rats

A description of the different behaviour of the [illegible] rendered by Richter (1954)

The wild Norwegian rat lives in an environment [illegible] constantly be on the alert and ready to fight [illegible] to defend itself against all kinds of enemies [illegible] owls and snakes as well as man It is a fierce [illegible] animal that attacks at the least provocation [illegible] advantage of the least opportunity to escape [illegible] *tense and breeds poorly*

In marked contrast the healthy domesticated [illegible] gentle and trusting does not bite unless [illegible] makes no attempt to escape It lives placidly [illegible] ment of the laboratory where food water [illegible] stantly assured Its only contributions [illegible] ing drinking grooming and mating [illegible] early age and with a rapid rate

The characteristic of the "run kept [illegible] of the wild rats They are far from [illegible] course of the generation or two that [illegible] they still keep up a "pecking order [illegible]

This difference in activity between domesticated wild and run kept rats would be expected to be reflected in their muscle force. True the wild rats were found to be significantly stronger than the domesticated rats (Figure 10), but between the large rats alone this difference was not significant. Since, moreover the relation between force and muscle tendon length was the same for all 3 groups the role of muscle force in the difference between the frequency of tendon rupture in the 3 groups must be assumed to be very slight.

Muscle tendon length foot length and excursion were least among the albino rats. The explanation may be an adaptation to walking function in the domesticated as compared with running and jumping function in the wild rats.

The separation force was found to be significantly higher in the wild than in the domesticated rats but owing to the numerous fixation ruptures the results do not permit the conclusion that the tendons or muscles of the wild rats are definitely stronger than those of the domesticated ones. The same reasoning applies to an evaluation of the elongation.

The explanation of the fixation ruptures must be the soft bones of the domesticated rats. It was distinctly felt that the manually operated drill slid easily through the calcaneus of the domesticated rats whereas it took both strength and patience to drill through the calcaneus of the wild rats. This is in keeping with Smith & Saville (1966) and Saville & Smith (1966) who found an increased calcium content and increased separation force in the bone after training.

The distribution of the rupture site shows that the frequency of rupture increased from a single tendon rupture in the domesticated albino rats to about 40 per cent tendon ruptures in the brown run kept rats and about 60 per cent in the recently captured rats. This distribution corresponds to the finding that athletic people are most exposed to tendon rupture (Arner & Lindholm 1959, Picaud et al 1966, Frings 1969).

The group of rats showing the highest frequency of tendon ruptures was that of wild rats that had been kept caged and inactive for 3 months after being captured. This group too did not show histological changes to explain the increased frequency of tendon rupture (Barfred 1971 a). Arner & Lindholm (1959) claimed that tendon ruptures in athletes who are out of training were caused by involution of the vessels resulting in avascular necrobiotic changes. This theory cannot be supported by the present histological findings. In this group the

separation force in relation to body weight and elongation in relation to muscle tendon length were significantly below the findings in the control group. Thus inactivity has led to greater rigidity and reduced separation force of the tissue.

Rollhäuser (1953-54) found a simultaneous decrease in the birefringence, an increase in water content and a reduction of separation force in relaxed tendons.

Akeson et al. (1968) after 3 months immobilization of canine knees found a 30 per cent reduction of mucopolysaccharides in the inferior patellar ligament. According to Mathews (1967) the mucopolysaccharides combined with non-collagen protein are important factors in the mechanical properties of the tissue.

It is possible that changes in the ground substance of the tendon have caused the increased rigidity and reduced separation force in the inactivity group as compared with the control group. These changes would not be detected in the histological examination performed (Barfred 1971 a).

Despite a significant difference in frequency of tendon rupture between the "run kept" rats and the inactivity rats the present study showed an amazing conformity between the measured parameters. Thus there is no indication of where to find the explanation of the difference in the frequency of tendon ruptures between these two groups, but as already mentioned bone strength may be a contributory cause.

SUMMARY AND CONCLUSION

Rupture experiments on the bone-Achilles tendon-muscle-bone unit in rats were performed on domesticated and on wild Norway rats of all ages and of both sexes. In addition one group of wild rats was investigated after having been in cages for 3 months following capture (inactivity) and one group of brown rats (first or second generation of wild rats) kept in a run all their lives.

The experiments were carried out on anaesthetized rats by rapid elongation of the muscle-tendon group with the calcaneus in 30° supination (or pronation), tetanic stimulation of the muscle and an initial length corresponding to the elastic equilibrium length. The muscle force, separation force and elongation at separation were measured in a material testing machine which is described.

The findings were as follows:

1 Tendon rupture could be induced only in large rats

2 *Tendon ruptures were found with increasing frequency in the order domesticated rats rats kept in runs wild rats and lastly the inactivity rats*

3 Tendon rupture could be induced at a lower body weight on *females than on males*

4 Muscle force was the same in males and females of the same body weight

5 Muscle force was less among domesticated than among wild rats

6 *The muscle force-muscle-tendon* length relationship was the same in all groups

7 Separation force was significantly greater in wild than in domesticated rats

8 *Separation force was lower in the inactivity group than among* the wild rats

9 Elongation at separation was less in the inactivity group than among the wild rats

It must be concluded The claim that a healthy tendon never ruptures on indirect violence does not hold for experiments on rats

An important cause why rupture experiments have not previously given rise to tendon rupture is that the experimental animals have not been selected with a view to their previous conditions of living

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PROCEEDINGS OF THE SCANDINAVIAN ORTHOPAEDIC SOCIETY
35th ASSEMBLY
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FRACTURE OF THE KNEE JOINT

LATERAL CONDYLAR FRACTURE OF THE TIBIA

Poul S Rasmussen (Gothenburg Sweden)

Controversy still exists as to the best way of treating these fractures Some surgeons take a very active attitude suggesting open reduction in all cases with more than 5 mm depression of the joint surface whereas others believe that a satisfactory result can be obtained in most cases by non-operative means

On the basis of an analysis of 260 patients treated during the years 1959–1965 it is suggested that the decision of operative or non-operative treatment should be based not on the radiological appearances of the fracture but mainly on the clinical findings

I found 184 (71 per cent) lateral fractures in the series with 37 split fractures 84 compression fractures and 63 combined split-compression fractures The compressive element causes a depression of part of the lateral tibial plateau This in turn in some cases upsets the lateral stability of the knee joint Whether this happens or not depends on the extent and localization of the compression more than upon its depth An anteriorly located compression makes the knee joint unstable in full extension while a posterior compression produces instability in slight flexion Even centrally located compressions and most compressions combined with a lateral split fragment often produce instability Only the compression that produces instability in full extension—and this can be determined by clinical examination only—should be treated by open surgery

Preliminary results to support these principles of treatment were reported and will be published in detail later

FRACTURES OF THE TIBIAL CONDYLES

Georg Bakalim & Eero Wilppula (Helsinki Finland)

The material comprises 196 personally followed patients with 197 fractures of the tibial condyles out of 291 cases treated in the Orthopaedic and Accidents Clinic Helsinki during the period 1962–1967 In 128 of the patients the fracture affected the lateral and in 38 the medial condyle Bicondylar fractures of the T and Y types were present in 31 More than half the injuries were sustained in road accidents 53 per cent were treated conservatively Out of the displaced fractures 70 per cent had been treated by operation

The results were assessed by the system of Hohl & Luck published in 1956 A correlation was found between the reduction and the end result Therefore efforts should be made to *obtain a good reduction often requiring operation* as severe cases cannot be repaired by closed reduction Injuries to ligaments are common and great attention should be given to their diagnosis and primary treatment Insufficiency of ligaments was found at follow up without condylar deformity in 26 cases and with condylar deformity in 14 Out of these cases only 4 had been diagnosed and sutured primarily In the presence *of condylar deformity damage* to the ligaments may occur later due to over stretching An exact reduction should therefore be the aim also out of regard to the ligaments Relatively long periods of immobilization were used average 9 4 weeks, and this need not prevent acceptable functional end results if active training of movements is controlled by the surgeon and quadriceps exercises are started during the period in plaster The patients were not allowed weight bearing for an average of 11 7 weeks It was not possible to demonstrate any correlation between the length of the non weight bearing period and the end result

A REVIEW OF 200 TIBIAL CONDYLAR FRACTURES

Hugh Dovey & Jan Heerfordt (Copenhagen Denmark)

All cases were treated in Bispebjerg Hospital Dept M Copenhagen with a follow up of 11/12–10 years

62 cases were operated mainly by Palmer s technique Cancellous kiel bone appears to be the ideal grafting material

Early mobilization gave the best final mobility and there was no evidence that it predisposed to lateral instability or valgus deformity Immobilization in corrective plaster did not seem to correct the valgus tendency

Permanent bony depression increased valgus and radiological osteoarthritis were directly associated but clinical results were appreciably poorer *only when* the valgus exceeded 10

Clinical results after operation were rather less satisfactory than after conservative treatment whereas radiological results were better after operation—independently of classification by fracture type or by degree of depression In each group *the operations have been done on the more serious lesions so presumably* something has been gained by operation

Both clinical and radiological results were better in cases where the meniscus was retained

X rays frequently showed marked permanent depression despite a good clinical result and arthrograms as well as autopsy specimens demonstrate that the joint surface is re formed by fibrocartilage It is possible that we attempt to achieve by operation a result that Nature herself can attain with less risk to the patient

FOLLOW UP ON 50 CASES WITH FRACTURES OF THE LATERAL TIBIAL CONDYLE TREATED PREDOMINANTLY BY OPERATION

Jan Heerfordt & Walther Mourit en (Copenhagen Denmark)

This study from the Department of Orthopaedic Surgery Rigshospitalet University of Copenhagen is an appendix to the one reported above from Bispebjerg

Hospital (hereafter called the BBH series) The shortest follow up period is 18 months As in the BBH series we used Hohl s classification into types and Hohl & Luck s follow up classification The material comprises displaced fractures of the lateral tibial condyle 12? cases of the BBH series may be assigned to the same group and were compared with the present material. The most essential difference between the two materials was found in the *group with > 10 mm primary depression* All patients of the present series were treated by operation whereas this was the case with only a little more than half the patients of the BBH series The clinical results were somewhat better in the present series than in that from BBH On the other hand the *group with 3-10 mm primary depression* showed better results in the BBH series which included a smaller percentage of operated cases With respect to the *primary* as well as the *persisting* degree of depression the results were identical in both series These findings would appear to indicate that it is rewarding to operate in the very severe cases and to abstain from operation in the milder ones Incidentally good and poor clinical results appear to be scattered rather capriciously over the series whether or not operation had been performed although the results seem to be to some extent dependent upon the *primary* severity of the injury In the BBH series mobilization of the knees had on the whole been allowed earlier than in the present series and a correspondingly better mobility had been obtained

TIBIAL CONDYLAR FRACTURES

Ulf Lucht & Søren Pilgaard (Århus Denmark)

A prospective investigation of 109 tibial condylar fractures from the period *1959–1968 was discussed 47 per cent of the fractures were treated by operation* The follow up examination indicates conservative treatment in non-displaced fractures and in fractures with a displacement of less than 10 mm The grading criteria of Mason Hohl & J V Luck (1956) were used in assessing the functional and anatomical results According to this grading there were 94 per cent excellent and good *functional* results in the group with a 3-10 mm depression when they were treated conservatively and 78 per cent excellent and good functional results when they were treated by operation The *anatomical* results were excellent and good in 59 per cent of the conservatively treated and in 61 per cent of the operated cases

In the authors opinion early active exercises are important for obtaining optimum results in fractures of the tibial condyles

CONSERVATIVE TREATMENT OF TIBIAL CONDYLAR FRACTURES

Jørgen G Ibsen & Niels Mossing (Glostrup Denmark)

Out of 87 patients admitted with tibial condylar fractures to Surgical Department A of the Glostrup Hospital Copenhagen during the period 1958–1969 71 with 72 fractures were seen after an average follow up period of 5.2 years

The treatment had been predominantly conservative No patient was treated primarily in a plaster cast. Only 11 patients had osteosynthesis Osteosynthesis was only performed in cases with one large tilted fragment Otherwise the treatment was non weight bearing or traction with early active training of knee

joint function The functional and anatomical results were classified according to the criteria of Hohl & Luck (*Journal of Bone and Joint Surgery* 1956 38 A 1001–18) An acceptable functional result (excellent + good) was obtained in 68 out of the 72 fractures whereas the anatomical result was acceptable in 50

It is concluded that the results obtained by the above mentioned therapeutic principle are satisfactory and that in assessing the late results the radiological appearances need not be attributed with decisive importance

OSTEOTOMY ON THE TIBIAL TUBEROSITY IN FRACTURES OF THE TIBIAL CONDYLE

Sven Olerud (Uppsala Sweden)

In the more extensive tibial condylar fractures the usual lateral incisions often afford a poor intra articular access This restricts the possibilities of reconstructive procedures In the cases of central depressions the problem may be solved technically by osteotomy of the lateral condyle a factor which greatly facilitates the reduction of the dislocated articular surface



Figure 1

Another possibility of a better approach is osteotomy [illegible] dividing the retinacula to both sides and reflecting the pa[illegible] Thereby the knee joint is rendered more easily access[illegible]

By the following 2 series of illustrations I merely want [illegible] possibility of using such a technique

The first case is that of a 17 year-old patient who sust[illegible] injury (Figure 1) when falling off his moped The larg[illegible] condyle is depressed The injury comprises mainly the [illegible] joint with an oblique position of the joint surface fragm[illegible] apparent from the tomographic exposures and in the [illegible] anterior fragment with attachment of the anterior cruc[illegible] separated from the eminence By the technique men[illegible] of the central parts of the joint was obtained After the fra[illegible] cleaned the lateral condyle could be placed almost acc[illegible] wire the fragment of the eminence as well as the [illegible] cruciate ligament could be united The radiological re[illegible] was extremely satisfactory The osteosynthesis was [illegible] advantage of immediate mobilization could be u[illegible] accident the patient had practically recovered the [illegible] in the frontal and in the sagittal planes and the flex[illegible]

The next case is that of a 4? year old man who [illegible] sustained a bicondylar depression fracture The [illegible] about 45 backward the lateral condyle is depress[illegible] medial condylar fragment by 3–4 mm By drilling [illegible] that the presupposition for a good basis of a tib[illegible] We therefore embarked upon osteotomy of the t[illegible] joint anteriorly This created a favourabl[illegible] tion of the tibial condyles Postoperative X rays [illegible] are reduced to an almost exact position

This technique involves a considerable exp[illegible] succeeding in satisfactorily fixing the tibial [illegible] should perhaps be reserved for special indica[illegible] access

DISCUSSION

B G Weber (St Gallen Switzerland)

The discussion whether shaft fractur[illegible] by open reduction and internal fixati[illegible]

It is easier to make the decisi[illegible]n [illegible] basis of the following calculation *On th[illegible]* restoration on the right the differen[illegible] [illegible] allo[illegible]ed expected

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		Primary fixation in plaster	Functional treatment	Open reduction + plaster fixation	Open reduction + rigid fixation + functional treatment
Union of fracture gaps		+	+	+	+
Restoration of function	mobility	—	+	—	+
	power	—	+	—	+
Restoration of congruence		—	—	+	+

Note that only the last mentioned therapeutic possibility offers the best chances of full recovery but only provided that the surgeon is experienced and the hospital conditions in favour of a low infection rate

Olov Lindahl (Linkoping Sweden)

The great question to the patient with fracture of the tibial condyles is whether he is going to have pain on function or even at rest after the fracture has united We do not yet know whether conservative treatment or operative treatment (both of the best quality with immobilization) affords better results Müller s table is a kind of propaganda for operation but does not pay regard to pain and aching These symptoms may easily be imagined to be on the whole more common following operative than following conservative treatment

Sten Friberg (Stockholm Sweden)

Dr Rasmussen mentioned in passing the desirability of avoiding an intraarticular procedure I am not sure that this is the right attitude The intraarticular changes are often greater than the clinical examination would lead one to believe For instance I have seen cases in which the meniscus was completely detached lying as a cord at the bottom of the depression

In answer to the chairman s question I should nevertheless like to warn against meniscectomies except on decisive indications It is true that slalom skiers and football players can return to their sport soon after meniscectomy However at the site of the meniscectomy osteoarthritis will often appear in 15–20 years In considering the indications for meniscectomy it must be borne in mind that the lateral meniscus is more important than the medial one to articular congruence The surface of the lateral tibial condyle is saddle shaped unlike that of the medial one which is biconcave

Lastly I should like to point out that according to analyses of insurance materials meniscectomized patients are to a marked extent receiving disablement pension i e having a disablement of 10 per cent or over

Hugh Dovey (Copenhagen Denmark)

Concerning the problem of removing the meniscus our results show that it should be retained if possible In our entire series there was only one patient with

symptoms that could possibly be attributed to a meniscus lesion and these symptoms were not severe enough to warrant treatment

In the operated cases both clinical and radiological results were better in cases where the meniscus had been retained and the two autopsy specimens showed definite thickening of the meniscus which formed a cushion covering the fracture surface to which it was effectively anchored by fibrous tissue

SUPRACONDYLAR INTRAARTICULAR FRACTURE OF THE FEMUR RESULTS OF OPERATIVE RECONSTRUCTION

Sven Olerud (Uppsala Sweden)

Supracondylar intraarticular fracture of the femur is difficult to deal with and opinions concerning its treatment are divided Neer et al (1967) on the basis of a material of 110 cases still recommend conservative treatment since internal fixation had given a very poor result in almost 50 per cent of their cases Since 1965 we have adjusted a surgical procedure for this type of fracture in the University Hospital Uppsala Sweden

Our experience is based upon a material with a 1–5 year follow up comprising 15 cases in the age range 15–77 years 6 were females The causes of the fracture were road accidents in 11 cases ice hockey in one and falling on stairs in 3 7 out of the 15 fractures were open the shaft of the femur penetrating the quadriceps muscle Moreover 4 patients had multiple injuries

The classification used by Neer and his associates was also used for the present material

Group 1 Wedged fracture with separated condyles but without major displacement ? patients

Group 2 Separated condyles and considerable displacement of the metaphyseal fracture, to the lateral or medial aspect 5 patients

Group 3 Separated condyles but in addition to a metaphyseal fracture also a femoral shaft fracture often comminuted 8 patients

5 of the fractures—all open— were treated immediately by operation After initial traction therapy 9 were operated upon within one week whereas one patient did not have the operation until 3 weeks after the accident

The operative treatment aimed at exact reconstruction and stability of the fracture Thus all the cases had osteosynthesis by an AO angular plate combined with a screw Adequate exposure of the distal end of the femur was obtained by osteotomy of the tibial tuberosity elevating the patella and the extensor apparatus The operative method is apparent from the following series of illustrations

A metaphyseal defect arising at the reduction was filled with a cancellous bone graft in 6 *cases 5 of which had open fractures*

Early postoperative mobilization was practised Weight bearing was allowed at the end of about 3 months

Complications Infection occurred in 3 cases All responded to adequate antibiotic therapy and surgical procedures *Pseudarthrosis* occurred in one case but following bone grafting consolidation was obtained. *Re fracture* occurred at the junction of the femoral shaft and the metaphysis after removal of the plate in one case

		Primary fixation in plaster	Functional treatment	Open reduction + plaster fixation	Open reduction + rigid fixation + functional treatment
Union of fracture gaps		+	+	+	+
Restoration of function	mobility	—	+	—	+
	power	—	+	—	+
Restoration of congruence		—	—	+	+

Note that only the last mentioned therapeutic possibility offers the best chances of full recovery but only provided that the surgeon is experienced and the hospital conditions in favour of a low infection rate

Olov Lindahl (Linkoping Sweden)

The great question to the patient with fracture of the tibial condyles is whether he is going to have pain on function or even at rest after the fracture has united We do not yet know whether conservative treatment or operative treatment (both of the best quality with immobilization) affords better results Müller's table is a kind of propaganda for operation but does not pay regard to pain and aching These symptoms may easily be imagined to be on the whole more common following operative than following conservative treatment

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Lastly I should like to point out that according to analyses of insurance materials meniscectomized patients are to a marked extent receiving disablement pension i e having a disablement of 10 per cent or over

Hugh Dovey (Copenhagen Denmark)

Concerning the problem of removing the meniscus our results show that it should be retained if possible In our entire series there was only one patient with

Results The majoritv of patients have obtained an extremelv good function However four of the oldest patients use a stick but only out of doors One of the infected patients has greatly restricted mobilitv of the knee joint and thus does not walk stairs normall All 15 patients are free of pain in their daily work However 4 report pain on exertion and another 3 feel changes in the weather 7 patients have an almost normal range of mobility i e more than 125 5 have 90–110 mobility 2 have 70–80 and one (one of the infected cases) has a range of only 25 4 patients show objectively a slight instability of the knee joint One patient exhibits a ≤ 5 varus deformit one a ≤ 5 valgus deformity and one patient only has a shortening of 2 cm

According to the criteria of Neer et al (1967) of the end results this operatively treated series shows despite the complications an excellent result in 12 cases a good result in 2 and an unsatisfactory result in one case

Our experience of operative treatment in supra intracondylar fracture of the femur is extremely positi e Unlike Neer et al we recommend stable internal fixation With access to suitable osteosynthesis material and a satisfactory technique it seems possible to achieve success even in very severe fractures of this type (Figure 1)

Reference Neer C. S Grantham S A & Shelton M L. (1967) Supracondylar fracture of the adult femur A stud of one hundred and ten cases *J Bone Jt Surg* 49 A 591–613

DISCUSSION

B nt Barfo l (Arhus Denmark)

The described approach obtained by drilling the tibi l tuberosit and reflecting the patella and quadriceps muscle affords an excellent approach to comminuted fractures of the distal end of the femur Treatment of the fracture by the AO system and fixation of the tibial tuberosity by a screw gives stability enough for movements of the knee joint to be instituted immediatel However frequentl there are large lacerations of the quadriceps muscle which have to be sutured In my opinion this indicates immobilization for about 3 weeks Thereafter there may be such tight adhesion of the muscles to the site of the fracture that the quadriceps has to be released by operation

OPERATIVE TREATMENT OF PATELLAR FRACTURES

Juhani Nummi (Haukilahti Finland)

248 operated ca es among 707 pateller fractures treated in the Clinic for Orthopaedics and Traumatolog Helsinki University Central Hospital, during the years 1961–1967 are presented 112 cases were operated upon by reconstructive methods 112 b partial excision and 24 by patellectomy Postoperatively the patients were immobilize l in plaster and taught quadriceps exercises

Complications occurred in 11 per cent including one death Slight wound inf c tion was most common 4 patients treated by cerclage sustained re fracture

The peri d of disability mean 121 days was shortest after partial excision One year postoperati ely 74 per cent of the patients mainly those treated by recon

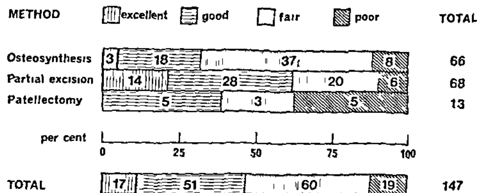
struction still had complaints Patients with a *long immobilization period had* most complaints especially limitation of movement

In 19 cases bone necrosis developed all but one after cerclage The convalescence was delayed and arthritic changes developed later but all cases united

At follow up examination 1-8 years later 155 cases were seen

19 were disabled or able to do only light work 14 per cent had no complaints 56 per cent were satisfied but had minor complaints 30 per cent were dissatisfied and had more severe complaints Arthritic changes had developed in 76 per cent

The end results (see figure) were best after partial excision unsatisfactory after reconstructive methods and most unsatisfactory after cerclage



DISCUSSION

K Harry Sorensen (Odense Denmark)

I should like to warn against primary patellectomy in comminuted patellar fractures as the torn extensor apparatus is *difficult* to suture There is apt to be tension leading to limitation of movement Instead cerclage should be performed even though the joint surface cannot be made smooth After union patellectomy may be performed secondarily At that time the extensor apparatus has healed It is our experience that patellectomy is very rarely indicated even after comminuted fractures (cf *Acta orthop scand* 34 198 1964)

POSTERIOR CRUCIATE LIGAMENT—RECONSTRUCTION BY TRANSPOSITION OF THE POPLITEAL TENDON

Bent Barfod (Århus Denmark)

A new method for reconstruction of old ruptures of the posterior cruciate ligament The tendon to the popliteal muscle is detached from the lateral femoral condyle and transposed into the intercondylar fossa where it is fixed to the femoral attachment of the posterior cruciate ligament (Figure 1) A patient who had this operation was seen after a follow up period of 3¼ years He had satisfactory function and in particular no difficulty in the form of unlocking the knee from an extended position

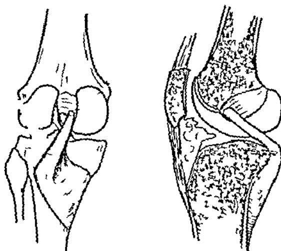


Figure 1

OPERATIVE TREATMENT OF RUPTURE IN THE MEDIAL COLLATERAL LIGAMENT OF THE KNEE

Arne Oster Kaj Okholm & Johs Hulgaard (Arhus Denmark)

A total of 5f knees with rupture of the medial collateral ligament were treated all by operation in the Orthopaedic Hospital Arhus during the period 1956–1967 Of these knees 50 were seen at follow up

The rupture affected predominantly youngish persons (84 per cent under 40) of the male sex (94 per cent) The most common cause was sport (72 per cent) Lateral instability tenderness and oedema at the ligament were the main symptoms and signs As a rule it was the deep ligamentous layer which was ruptured but in nearly half the cases both the deep and the superficial layers were ruptured and most often in the proximal part A meniscus injury was present in about 30 per cent and injury to the cruciate ligament in almost half the cases

At follow up 2½–13 years after the operation all the patients were working 20 per cent of the athletes had given up their sport because of the injury 90 per cent of all the patients had complaints in the form of occasional pain or a feeling of instability in the knee The poorest results were recorded among patients who had the operation at a late stage and at an age over 40 Among the poor results many had atrophy of the thigh The common injuries to the cruciate ligaments contributed to the persisting symptoms from the knee

SURGICAL TREATMENT OF OSTEOARTHRITIS OF THE CARPO METACARPAL JOINT OF THE THUMB

Andr as Weilby (Hørsholm Denmark)

A total of 48 cases have been treated with improvement of the pain in 44

T chn cal complications 2 case of mild dystrophy 9 cases of injury to a

branch of the radial nerve 2 cases of Kirschner wires drilled into the carpal canal and 2 cases of broken wires in bones

The operations were as follows

Arthrodesis of the carpo metacarpal joint of the thumb (18 operated 3 re operated) Bandage worn for more than 3 months Bony union in 12 fibrous ankylosis in 6 Good stability in the carpo metacarpal joint of the thumb restricted mobility of the thumb as a whole and normal strength of grasp

Complications Inadequate position in 2 cases progressing osteoarthritis in the joint between the greater multangular bone and the navicular bone in 2 cases (milder in 5)

Indication Young patients sequelae of fractures and heavy work

Contra indications Osteoarthritis between the greater multangular and navi cular bones stiffness of the distal interphalangeal joint and in the metacarpo phalangeal joint

Excision of the greater multangular bone (17 operated cases) Bandage for 6 weeks 5 patients had varying degrees of carpo metacarpal instability Mobility in the joint 75 per cent of normal Appreciably reduced strength in movements of the 1st metacarpal bone and in grasping

Complications Instability in the first carpo metacarpal joint (counteracted by tightening the capsule shortening of the abductor pollicis longus and fixation of the 1st metacarpal bone in an abducted position by a Kirschner wire)

Indication Patients with light work who want good mobility stiffness of the interphalangeal and metacarpo phalangeal joints of the thumb adduction con tracture of the thumb osteoarthritis between the navicular bone and the greater multangular bone

Contra indication Heavy work

Alloplasty (Swanson prosthesis) (13 operated cases 2 prostheses removed) Bandage for 6 weeks Better stability in the carpo metacarpal joint of the thumb and better mobility than following excision of the greater multangular bone Strength in movements in the carpo metacarpal joint and in grasping almost normal

Complications 4 cases of dislocation subluxation and dislocation of the prosthesis out of the shaft of the metacarpal bone (Counteracted by bandaging in an abducted extended position which also secures a correct position)

Indication As that for excision of the greater multangular bone

Contra indications Pre existing contracture of the 1st web space

DISCUSSION

Bent Barfod (Arhus Denmark)

This condition is not uncommon but it is difficult to decide which treatment is best There is invariably more or less degeneration of the carpo meta arpal joint capsule and on the background of the named dislocations of the Swanson prostheses it was asked whether the capsule had been strengthened in the course of the operation for instance by a piece of the abductor pollicis tendon

ARTHRODESIS OF THE WRIST

A. Rechnagel (Copenhagen, Denmark)

During the period 1962–1968 a total of 60 wrist arthrodeses were performed in the Orthopaedic Hospital, Copenhagen, partly for pain or contracture and partly in order to stabilize the wrist in cases of various pareses.

The standard technique is an ulnar approach, resection of the head of the ulna and fixation by a bone graft, as a rule from the iliac crest.

In cerebral palsy arthrodesis was performed by wedging the radius into the carpus in order to obtain shortening.

With few exceptions all the patients have been relieved of pain. In osteoarthritis and lunate malacia 17 out of 22 patients are back to normal work; 4 are not working because of other diseases. In spastics the result was almost exclusively cosmetic improvement.

A graft from the iliac crest is better than one from the ulnar bone, 4 out of 14 ulnar grafts having failed, while all 31 with iliac grafts united.

Twelve of the patients definitely did not have carpo-metacarpal union, but only 2 of them had mild pain when working, so that it does not seem to be necessary to carry the arthrodesis as far as the base of the metacarpal bones.

RECURRENT EFFUSION IN THE KNEE JOINT
FOLLOW-UP ON 41 CASES

Veijo Vahvanen & P. V. S. Koskinen (Helsinki, Finland)

The series comprised 41 patients showing recurrent mono-articular effusion of the knee joint. The onset of the disease was "subacute" and the causes obscure. Obvious injuries, infections or other diseases of bone or cartilage were excluded. The series was classified into different diagnostic groups on the basis of clinical examinations in hospital. Attention was mainly directed at the aetiology and the results of operative and conservative treatment in cases of doubtful synovitis. In 7 cases (17 per cent) the histological appearance of the synovial membrane

Table 1. Treatment in the different diagnostic groups

Group	Synovectomy	Arthrotomy etc.	Osteotomy	Conservative
Doubtful synovitis	6	2	0	11
Effusion and osteoarthritis	1	3	4	1
Traumatic effusion	3	2	0	5
Rheumatoid synovitis	2	0	0	0
Pigmented villonodular synovitis	1	0	0	0
Total	13	7	4	17

Table 2 Results in 37 followed cases

	Good	Fair	Poor	Total
Operative treatment	12	5	7	24
	50%	21%	29%	100%
Conservative treatment	6	4	3	13
	46%	31%	23%	100%
Total	18	9	10	37
	49%	24%	27%	100%

Table 3 Results in operatively and conservatively treated cases in the different diagnostic groups

Group	Operative treatment			Conservative treatment		
	Good	Fair	Poor	Good	Fair	Poor
Doubtful synovitis	5	2	1	4	0	3
Effusion and osteoarthritis	2	3	3	0	1	0
Traumatic effusion	3	0	2	2	3	0
Rheumatoid synovitis	2	0	0	0	0	0
Pigmented villonodular synovitis	0	0	1	0	0	0
Total 37 cases	12	5	7	6	4	3

resembled that seen in rheumatoid arthritis Operative treatment was used in 24 cases (59 per cent) conservative treatment in 17 (41 per cent) (Table 1) Among the conservatively treated cases the end result was poor in 3 4 patients were lost to follow up The results of operative treatment were good in 12 cases (50 per cent) fair in 5 (21 per cent) and poor in 7 cases (29 per cent) (Tables 2 and 3) The operative methods were synovectomy (13 cases) debridement or some minor procedure (7 cases) and osteotomy (4 cases) Synovectomy was successful in 8 cases (62 per cent) while the result was poor in 5 (38 per cent) The results of synovectomy would probably be even better in a series selected on stricter indications The diagnostic and therapeutic problems were discussed

A CLINICAL AND SEROLOGICAL STUDY ON THE EFFECT OF SURGICAL SYNOVECTOMY IN RHEUMATOID ARTHRITIS

Jørgen Sommer (Odense Denmark)

This investigation comprises 64 patients with active rheumatoid arthritis who underwent during a 2 year period surgical synovectomy of one or more joints on the average 2 large and 3 small joints in the Department of Orthopaedic Surgery O of the Odense Hospital

Immediately before the operation the patients had a complete clinical examination including the status of their joints and X ray examination of all joints Moreover all had preoperative serological studies.

Postoperatively the patients had serological studies 1 2 3 and 4 weeks serological and clinical studies including the complete joint status 3 6 12 and 24 months after the operation on the last occasion with X ray examination of all joints The last patient was operated upon in November 1968 so that for a small part of the material the study has not been completed.

It may be concluded that so far the local effect of surgical synovectomy in active rheumatoid arthritis has been good Mobility has improved the pain capsular swelling and accumulation of fluid have subsided or disappeared and strength has increased However the disease progresses in the unoperated joints (active as well as inactive) and partially also in the operated joints though more slowly Accordingly we are now more reserved in using surgical synovectomy for rheumatoid arthritis

PYROPHOSPHATE SYNOVITIS

Göran Sundén & Anders Bjelle (Lund Sweden)

The concepts articular chondrocalcinosis and pseudoarthritis were discussed and a new terminology was suggested

The condition is much more common in an orthopaedic clientele than is apparent from the current literature The cases encountered since New Year 1969–1970 in the Lund University Clinic were reported Certain tendencies in the symptoms and signs in this group of patients were discussed

DISCUSSION

Bo Nilsson (Malmoe Sweden)

Is there any proof that synovectomies will in the long run affect the progression of rheumatoid changes in the operated joints?

F Hjalmar Larsen (Copenhagen Denmark)

The originally positive attitude to synovectomy is cooling off in some quarters Control materials would be of interest Some measure of control is available e g in a c with bilateral arthritis of the knees It is encouraging to note how often the patients ask for the same operation on the other side

The variations in the views may be due *inter alia* to different operative technique It is presumably decisive to the late result to make the synovectomy

radical Thus in the knee the synovial membrane must be removed from the posterior aspect and from below the menisci In some joints it is difficult to attain a truly radical operation

At any rate we can agree that it has not proved harmful to remove the diseased synovial membrane which has a tendency to erode the articular cartilage

HIP ARTHROPLASTY COMPLICATIONS AFTER TOTAL HIP REPLACEMENT BY ROTATION ENDOPROSTHESIS

B G Weber (St Gallen Switzerland)

Total hip replacement has been used at the Department of Orthopaedic Surgery of the Cantonal Hospital St Gallen Switzerland since 1961 On the average 450 operations are performed annually in the treatment of osteoarthritis of the hip joint osteotomies fusions total hip replacements

In two series 1220 total hip prostheses have been implanted (161 to March 1967 455 Mueller April 1967 to July 1970 765 Weber)

In the course of this period three main problems have arisen

1 Infection
2 Anchorage
3 Wear

1 *Infection*

According to Charnley s findings sterility conditions in our conventional theatre are in disfavour of asepsis Agar plate cultures exposed at different times throughout the day and night show different quantities of bacterial growth few colonies during the resting time numerous colonies during the operative programme In the air there are only *Staph albus* in variable concentrations and saprophytes of equal quantity throughout the day

In 50 per cent of sterile wounds immediately before wound closure the same bacteria are found but together with *Staph aureus* one third as often as with *Staph albus*

Infected total hip prostheses showed the same bacteriology as the non infected wounds except that a small number were contaminated with streptococcus All these infections appear to have been airborne at the time of the operation

The first series of 528 total hip replacements reported by Mueller including the above mentioned 455 cases from St Gallen showed at the end of 1967 an infection rate of 5 per cent In the summer of 1970 however the infection rate had risen to 7 5 per cent as further late infections had appeared

In our own series of 765 total hip replacements from 1967 to July 1970 the infection rate is 2 5 per cent

Both series are from the same hospital operated upon in the same theatre and subjected to the same conditions with one exception

As no sterile enclosure was available we have tried to increase the patients resistance by means of an active vaccination with polyvalent vaccine prepared from the current strains of staphylococci

Table 1 shows the infection rate from 1967 to 1970 in relation to vaccination

Table 1

Year	Total	Infection	Per cent	Vaccination
1967	124	11	10	0
1968	155	3	2	133
1969	310	4	1.3	300
1970 Jan.–July	176	1	0.6	176
	765	19	2.5	609

The more consistently the vaccination was done prior to the operation the more uncommon was infection

Analysis of the 19 infections shows

Without vaccination	14 cases
With incomplete vaccination	3 cases
With full vaccination	2 cases

In 1 case streptococci and in 1 case coli septicaemia from cholecystitis

The items shown in Table 1 encourage us to go on using vaccination and to earch for scientific proof of its efficiency

2 *Anchorage*

14 out of 765 total hip prostheses have worked loose Table 2 shows the possible reasons for loosening

Deficient implant	4
Heat damage	4
Failure of material	2
Unknown	4 = 14 cases of the present series
McKee	2
Teflon	1 = 3 further cases

D f i nt implants are those which show high friction between the components (4 Protek McKee types with sliding bearings)

H at damage coagulation of bone collagen because of too large an amount of bone cement is believed to be respon ible in 4 instances of loosening

Fa lure of mat rial One fracture of a Protek stem and one dislocation of a Pr tek socket out of the cement bed

In four cases the rea on f r l o ening are unknown

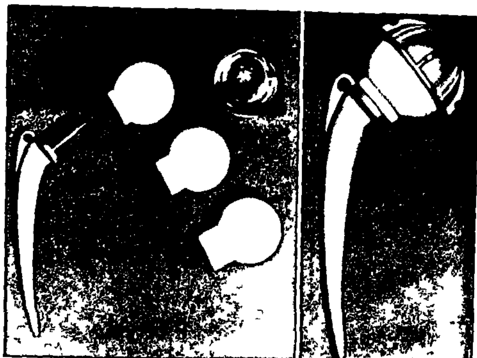


Figure 1

Two McKee originals showed high friction between the components One earlier case with a teflon socket showed gross loosening of the acetabulum

Total hip replacement with ideal congruence seems to provide sufficiently low friction to exclude loosening due to impact between the components Other implants of poorer technical quality however are prone to loosening

A large quantity of bone cement favours loosening Since we started using a small amount of cement and cooling during polymerization no further cases of loosening have occurred

3 *Wear*

In our material and in Mueller s (as far as we can assess the cases from occasional follow up) no wear is to be seen so far neither in the Charnley type nor in the McKee type arthroplasty It is important to mention that the prostheses used are Mueller s modifications produced in Switzerland (Protek) Not only these conventional types but also our own rotation trunnion bearing prosthesis implanted during a period of 2½ years in 510 instances have shown most encouraging results In 4 of these cases the prosthesis was removed one or two years after insertion At technological testing the wear *per annum* was found to have been 3/100 mm The congruence of the joint surfaces was not impaired at all

Figure 1 shows the design of this prosthesis

Our prosthesis is designed with regard to wear the plastic only is subject to wear not the metallic components After wearing for an unknown period and

the plastic heads will have to be replaced and the cemented distal components can be left *in situ* This would make the exchange of a worn artificial hip joint a minor operation

4 *Mortality*

Six patients out of 65 with total hip replacements died during the follow up period all of cardiovascular causes at an avera e age of f7 years No fatal or less seriou complications occurred during the operation itself

5 *Dislocation*

Four replaced hips out of 765 had dislocated within three weeks after the im plantation All could be reduced under general anaesthesia and there were no recurrences after a bed rest of three weeks

6 *Nerve damage*

Seven patients showed nerve damage	
Peroneal nerve palsy	4
Femoral nerve palsy	2
Sciatic nerve palsy	1

These damages have regressed but not always completely They are caused by a rough technique and not sufficiently careful insertion of the Hohmann retractors during the operation

Summary

Our experience of complications to total hip replacement can be summarized in the following recommendations

1 The infection rate may be lowered by increasing asepsis in the theatre Active vaccination with polyvalent staphylococcus vaccine seems to be effective.

2 The rate of loosening can be controlled by the use of prostheses with low friction and by avoiding large amounts of bone cement Small amounts of cement prevent heat damage to bone collagen Cooling during setting is logical

3 Wear depends on many factors and is inevitable as every machine shows wear Therefore the exchange of worn prostheses should be easy In this respect the trunnion bearing type or prostheses based on similar ideas may have the best chance of extending the indication for total hip replacement to younger Indi iduals

A film was presented to show the trunnion bearing total hip replacement the prosthesis the special instruments (guides for the metallic components reamers *retractors) the operation the after treatment and early results*

PRELIMINARY RESULTS OF TOTAL HIP REPLACEMENT IN SOPHIES MINDE ORTHOPAEDIC HOSPITAL, OSLO

Pål Benum (Oslo Norway)

After 89 total hip replacements (17 McKee 3 Mueller and 69 Weber prostheses) the following complications occurred

1 deep and 1 superficial infection 1 perforation of the femur 1 peroneal nerve damage 1 peripheral arterial embolism 1 loosening of a McKee prosthesis

Out of 64 patients seen 3 months after the operation 61 were satisfied 1 was suffering from severe pain and 7 felt slight pain

The average range of movement was found to be flexion + extension 83 abduction + adduction 36 rotation 33

The influence of some factors upon the postoperative range of movement was studied

The type of prosthesis McKee or Weber did not seem to be of any importance The preoperative range of movement was undoubtedly of some importance The average flexion + extension postoperatively for the different groups was 0–30 73 30–50 77 50–70 84 70–90 100 90– 103 The few poor results were found within the first two groups Patients with a fused hip on the opposite side had a lower average range of flexion + extension than patients with a mobile hip on the opposite side (70 as compared with 90 preoperative difference 6)

A variation of the lateral inclination of the acetabular component of the Weber prosthesis within 30–60 does not seem to be of any importance to the range of flexion + extension and abduction

TOTAL HIP REPLACEMENT BY THE METHOD OF McKEE FARRAR

Stefan Haraldsson (Harnösand Sweden)

During a period of 18 months 102 total hip replacements have been done by the McKee Farrar prosthesis at the Orthopaedic Clinic Harnosand Sweden

Modifications of the original procedure Moore's posterior approach posterior to the ilio femoral ligament which is of importance to hip stability No screws in the margin of the acetabulum at least six 12 mm wide and 1 cm deep holes are drilled into the acetabulum The holes are undermined Operative period about 1 hour

Ambulation and full weight bearing on the day after the operation Walking trained from the 2nd day Discharge at the end of 3–4 weeks

Ten patients had the operation on both sides including two with fixed deformities who had both operations in the same stage Average age 67 years Operative diagnoses 80 hips osteoarthritis 18 sequelae of femoral neck fracture 4 rheumatoid arthritis

Complications Two patients who were already being trained in walking died 10 and 15 days respectively after the operation both of pulmonary emboli Two patients had dislocation of the prosthesis immediately after the operation but no relapse after reduction One patient sustained an intertrochanteric fracture in the course of the operation but it united without complications Two deep infections with fistulation from the hip joint appeared 10 and 5 months respectively after the operations There were no complications in the form of myositis ossificans or injuries to the sciatic nerve

Preliminary follow up is available for 80 hips after periods ranging from 1–18 months 95 per cent have been completely or almost completely relieved of pain and all are better (Figure 1)

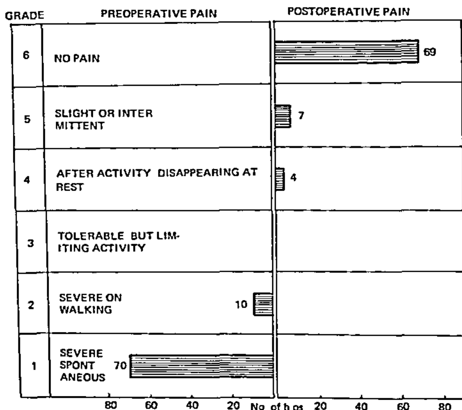


Figure 1

The postoperative walking ability had improved in 93 8 per cent (Figure 2) and 71.3 per cent of the hips have an improved range of mobility

The primary results are considered better than following other hip joint operations on the same indications The posterior approach reduces the soft tissue injury shortens the operative period permits bilateral operations in the same stage early weight bearing and facilitates re-operation if required As various aspects concerning the long term re ults are still unknown we must for the time being reserve the method for elderly patients with the exception of special cases In such cases the patients must be prepared for the possibility of having to undergo re-operation later if the total prosthesis does not keep for a sufficient length of time

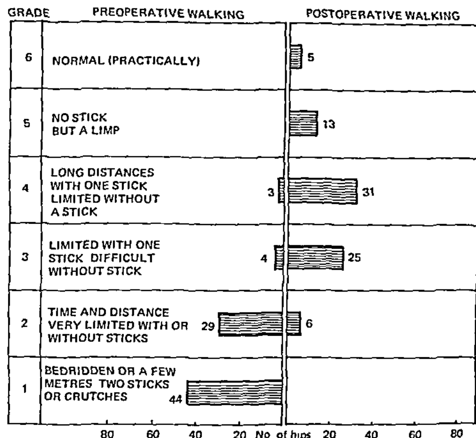


Figure 2

RESULTS AND TREATMENT OF COMPLICATIONS TO McKEE FARRAR TOTAL HIP ARTHROPLASTY

Erik B Riska (Helsinki Finland)

66 McKee Farrar hip arthroplasties were performed on 58 patients average age 67 years *during 1967–1970 All the patients were operated upon by the same* surgeon Two patients were under 50 years of age 25 were over 70 at the time of the operation Two had the operation in 1967 27 in 1968 22 in 1969 and 15 in early 1970 The larger type of endoprosthesis was used in 42 cases the smaller size with a short neck in 11 cases and the type with a long neck in 13 cases No prophylactic antibiotic treatment was given 34 patients were treated prophylactically by anticoagulants

After the first operation the result was excellent in 45 cases (Figure 1 good in 6 fair in 5 and poor in 10 The result was excellent in all cases with the smaller size of endoprosthesis Deep infection occurred in one case thrombo



Figure 1 Osteoarthritis in a 65 year old woman 15 months after a McKee Farrar arthroplasty with the smaller size of endoprosthesis with a long neck

Figure 2 Tissue between the bone and acrylic cement 16 months after the replacement operation Van Gieson × [illegible]00

phlebitis in 9 loosening of the cup in 7 loosening of both components in 7 a late fracture of the femoral shaft in 2 cases and myositis ossificans like tissue around the hip joint in 2 cases

In the infected case the endoprosthesis was removed The patients with post operative thrombophlebitis were cured with anticoagulants In 5 cases re fixation of the cup was done—with good results In 3 cases both components were re fixed and in four cases a new endoprosthesis of smaller size was inserted—with a good *final result in 6 cases Late fractures of the femoral shaft* were treated by 40 osteosynthesis

According to the histological examination of the tissue between the bone and acrylic cement the fibrous tissue was necrotic containing a few giant cells and necrotic bone fragments but no signs of infection could be seen (Figure 2) Loosening of the cup or of both components in six cases was due to technical errors but no definite explanation could be given in the remaining 8 cases

RING S TOTAL HIP REPLACEMENT

I Adorjan V Mouritzen & K Rechnagel (Copenhagen Denmark)

In the Orthopaedic Hospitals in Copenhagen and Kolding Denmark 60 hip joint alloplasties by the method of Ring have been carried out ince 1967 As the results of this operation have so far not been reported by others than Ring himself we felt justified in submitting an analysis of the first 46 operated hips and report on the technical difficulties and complications

Ring s prosthesis differs from other total prostheses in being fixed purely mechanically (i e without cement) The acetabular component is securely screwed and countersunk into the iliac bone whereas the femoral component is in principle an ordinary Moore prosthesis

Out of 41 hip joints seen at follow up 3 showed good results with less pain or none better walking ability and better mobility In cases where contracture had been present it had been relieved Eight patients still had some pain but had on the whole been relieved of pain at rest

Two prostheses have been removed one because of infection and one because of a poor technique the acetabular component having been placed in a transverse position It is important to place this component in a steep position parallel to the weight transmitting column of the iliac bone

So far Ring s prosthesis has proved a good alternative to the cemented types *but we still do not know the long term results*

TOTAL HIP REPLACEMENT BY THE METHOD OF RING

Karl Erik Olsson & Hilding Wet enstein (Stockholm Sweden)

During the period January 1968 to June 1969 a total of 53 hips were operated upon at the Orthopaedic Clinic of Norrbackainstitutet Stockholm Of these 53 hips 39 were from unilateral and 8 from bilateral cases

The postoperative follow up period averaged 1 5 years and the average age of the operated patients was 68 years

In the unilateral cases the indications were pain at rest and on weight bearing in 70 per cent and pain only on weight bearing in 30 per cent

The diagnoses were osteoarthritis and sequelae of malunion of femoral neck fractures in 80 per cent dysplasia, coxa plana etc., in 20 per cent. Postoperatively and during the first postoperative months external wound infection occurred in 4 cases and thrombosis (clinically diagnosed) in 6

22 patients have obtained distinct improvement relief from pain and improved walking ability and the same applies to another 6 in whom however the walking ability is not quite so good In 9 the pain is unchanged after the operation Among these latter cases 3 had deteriorated after having enjoyed a good result for 1 5 years Primary cementing of the femoral component of the prosthesis does not seem to result in less pain or in a better prognosis However the pain has been eliminated following re-operation cementing a loose femoral component

All the patients subjected to bilateral operation had had severe pain and very poor walking ability prior to the operation All were assessed as improved at follow up

DISCUSSION

Langenskiold (Helsinki Finland)

Why keep the patients in bed for 4 days after the operation instead of allowing weight bearing at once?

M Foss Hauge (Oslo Norway)

What is the nature of the contact between the cement and the bone? Can an inorganic material be glued" to an organic one?

I G Hallen (Falun Sweden)

Out of 130 total hip replacements (first McKee Farrar later Charnley) 3 developed infections 3 inexplicable walking pain and 3 sciatic pain one at the end of 2 months and the other one at the end of 8 months One was subjected to operation and an exostosis was found to have caused the pain which was relieved after its removal What is the cause of socket loosening?

I Alork (Oslo Norway)

The patients should be ambulated on one of the first postoperative days but should wear a boot with a cross bar when lying down to control the rotation of the leg

F Thomasen (Århus Denmark)

I am against this boot—it prevents the mobility of the leg

Knud Jansen (Copenhagen Denmark)

There is no definite conclusion from the papers In my opinion the patients should use crutches during the first 3 months while reconstruction of the bone is taking place The problem of shock absorption is probably of importance with regard to the loosening of the cups

B G Weber (St Gallen Switzerland)

In 765 cases we have had only one fatal embolism 2-3 per cent developed haematomas but they were evacuated a few days after the operation

John Charnley (Wrightington England)

Felt that deep venous thrombosis was a disease different from embolism Fatal embolism is very rare Did not feel that it was of any importance whether the patient was kept in bed for 4 days

There is no direct contact between the bone and the cement only a moulding of the bone As for the generation of heat it only acts as pasteurization! The bone becomes sterile and well suited for ingrowth of new bone

McKee requires anteversion to prevent flexion blockage but then there is an increased risk of dislocation and loosening

IMMEDIATE EFFECT OF OSTEOTOMY ON THE INTRAMEDULLARY PRESSURE IN THE FEMORAL HEAD AND NECK IN PATIENTS WITH DEGENERATIVE OSTEOARTHRITIS

Carl C Arnoldi Rudolf Lemperg & Håkan Linderholm (Umeå Sweden)

Recently Arnoldi Linderholm & Mussbichler (to be published) demonstrated a considerable hypertension in the bone marrow of the proximal part of the femur in patients with advanced stages of degenerative osteoarthritis of the hip joint Simultaneous examinations by means of intraosseous phlebography indicated that the high pressure is due to impaired venous drainage from the femoral head and neck

The present study is concerned with the immediate effect of intertrochanteric osteotomy and denudation of the femoral head—as performed in Smith Petersen cup arthroplasty—upon the intramedullary pressure in the proximal part of the femur

Table 1 Intramedullary pressures in the femoral head and neck before and after intertrochanteric osteotomy (first series)

	Head pressure mm Hg			Neck pressure mm Hg		
	Before osteotomy	After	Difference	Before osteotomy	After	Difference
n	Mean (Range)	Mean (Range)	Mean (Range)	Mean (Range)	Mean (Range)	Mean (Range)
5	74 7 (58 1–88 7)	50 1 (37 0–59 7)	24 6 (17 0–28 5)	60 0 (43 3–70 2)	32 4 (1[illegible] 7–43 3)	27 6 (20 9–40 0)

Intramedullary pressures were determined by means of two metal needles introduced into the bone marrow One needle was placed with the tip in the femoral head the other one with the tip in the neck Pressure measurements were

performed before and after osteotomy or femoral head denudation In the latter procedure cartilage and cortex were removed and cancellous bone laid bare in a window measuring four by four cm

Five patients were examined before and after osteotomy and four patients before and after head fenestration All patients showed abnormally high pressures before the operation The result of both procedures was an immediate and significant fall in pressure at both points of measurement (Tables 1 and 2)

Table 2 Intramedullary pressures in the femoral head and neck before and after fenestration of femoral head (second series)

	Head pressure mm Hg			Neck pressure mm Hg		
	Before fenestration	After	Difference	Before fenestration	After	Difference
n	Mean (Range)	Mean (Range)	Mean (Range)	Mean (Range)	Mean (Range)	Mean (Range)
4	49 8 (37 7–64 4)	38 0 (23 3–59 0)	11 8 (5 4–14 3)	40 2 (31 4–55 5)	22 6 (13.3–38 8)	17 6 (11 5–25 9)

In our opinion the severe rest pain characteristic of advanced osteoarthritis is due to the abnormally high intramedullary pressure The immediate relief of pain after osteotomy or Smith Petersen arthroplasty may be due to the reduction of pressure

CALVÉ PERTHES DISEASE
MACRO AND MICROSCOPIC OBSERVATIONS

E Hjalmar Larsen & Ing Reimann (Copenhagen Denmark)

The treatment of Calvé Perthes disease by intertrochanteric osteotomy was associated with arthrography and inspection of the femoral head together with histological examination of a biopsy taken as a wedge of the articular cartilage including part of the ossification centre from the anterior aspect of the femoral head

Fourteen hip joints have been examined in different stages

In the early stages of the disease more or less scattered necrosis of the bone was found together with irregular proliferation in the basal part of the articular cartilage In the later stages there was remodelling of the bone partly by osteoblastic apposition and partly by irregular endochondral ossification The non ossified articular cartilage was found to be thicker than normal In the later stages large islands of cartilage were frequently observed situated inside thick formations composed of necrotic and new formed bone tissue This is taken to correspond to the radiological picture of the fragmentation while the thick bone formation seems to give rise to the radiological picture of sclerosis On the other hand there were no cases of collapse of the articular cartilage or trabecular bone

On arthrography and on gross inspection it was noted that even late in the

fragmentation stage there was only little or no contour disturbance of the femoral head

The examination did not include the epiphyseal plate or the metaphysis where the primary and perhaps most pronounced changes might be expected

It is concluded that the deformity of the femoral head seen radiologically in the late stage of Calvé Perthes disease is caused by irregular ossification of the previously non ossified articular cartilage during the revascularization which follows upon the primary necrosis On the other hand the observations do not indicate any mechanical collapse of the head In the treatment of this disease therefore adjustment of the position of the femoral head in order to secure a maximum of contact with the acetabular wall and thereby induce a spherical shape during re ossification seems to be more logical than treatment which primarily aims at relief from weight bearing

DISCUSSION

Hans Bohr (Refsnæs Denmark)

In connection with Hjalmar Larsen s paper on biopsy specimens in Calvé Perthes disease densitometric studies of the femoral head were reported These studies revealed that during the early stage of condensation there is generally a question of only relative sclerosing as compared with the surrounding bone there being no difference in the density of the femoral head on the diseased and the unaffected side In the course of the subsequent three months however the density of bone increases on the diseased side without there being signs of bone compression This indicates that new formation of bone is taking place in the femoral head

LEGG CALVE PERTHES DISEASE

Jorgen Laurit en (Arhus Denmark)

Ambulatory treatment by non weight bearing using a wheel chair and a strap keeping the hip joints flexed has been practised at the Orthopaedic Hospital Arhus in all cases since 1957 114 consecutive unilateral cases were studied In 19 of the patients the treatment had not been properly carried through The patients treated in wheel chair were compared with 82 ambulatory patients treated by Thomas splint 79 treated by strict bed rest in hospital and 113 treated by bed rest with intermittent traction The cases treated by Thomas splint and by poorly performed wheel chair therapy showed fewest spherical femoral heads Traction therapy and correct wheel chair therapy gave the most favourable results

Factors of great importance in attaining a spherical shape in primary healing and thereby a good prognosis are also the patients ages and the degree of necrosis Those whose treatment is started latest show on the whole the most severe degrees No therapeutic method had afforded particularly good results in patients over 8 years of age Sex and radiological stage at institution of treatment are of im portance in attaining good epiphyseal quotients girls and patients treated late showing the poorest results Proper performance of wheel-chair therapy was independent of social and housing conditions

A 4 YEAR PROSPECTIVE STUDY OF TWO DIFFERENT THERAPEUTIC REGIMENS FOR NEWBORNS WITH CDH

Hans Emnéus & Kare Undeland (Uddevalla Sweden)

The authors have followed two different lines in treating newborns with CDH Emneus treated his infants with a von Rosen frame for only 6 weeks and in doubtful cases did not hesitate to use over treatment for 6 weeks Undeland treated his patients with a von Rosen frame for 12 weeks and in doubtful cases examined his infants under anaesthesia to be able to exclude the stable hips The material comprises 140 newborns out of the 17 000 from the maternity wards of the hospitals in Uddevalla Kungalv Lysekil Stromstad Vanersborg Trollhattan and Backefors during the years 1965–1969 Of these 140 infants 76 had obvious CDH and the remainder doubtful CDH If only the obvious cases are included the frequency is 0 45 per cent 82 cases of the material were treated by Emnéus and 59 by Undeland All the patients now have normal hips with one exception in which there is a suspicion of dysplasia of the acetabulum but no dislocation

Definite cases treated for 6 weeks Emnéus	Doubtful cases treated for 6 weeks Emneus	Definite cases treated for 12 weeks Undeland	Doubtful cases examined under anaesthesia Undeland
35	47	33 8 41	24 8 16

The last column of the table means that of 26 doubtful cases examined by Undeland under anaesthesia 8 were found to have definitely unstable hips and were treated with a von Rosen frame for 12 weeks The remaining 16 had no treatment at all but were followed during their first year of life

Conclusions Clinical investigation using Ortolani s test during the first week of life is the method of choice Radiography is not necessary until the age of 4–6 months In doubtful cases over treatment may be given or the infants may be examined under anaesthesia so that the definitely unstable hips may be selected Six weeks of treatment in a von Rosen frame is sufficient

ENDOPROSTHESIS MADE OF CERAMIC. AN EXPERIMENTAL STUDY ON RABBITS

Erik B Riska (Helsinki Finland)

The ceramic endoprosthesis was made of kaolin feldspar and sand with alkaline aluminium silicate at the Arabia China Factory Helsinki The heat tolerance of ceramic is over 1300 C, compression tolerance 5000 kg/cm bending tolerance 1000 kg/cm² when made by machine but less than 1000 kg/cm² when made by hand Ceramic is resistant to alkalis and acid electrostatically inactive and not subject to corrosion

Replacement operation was performed on 19 rabbits aged 8–10 months in 15 of the experimental animals under fully sterile conditions The follow up periods

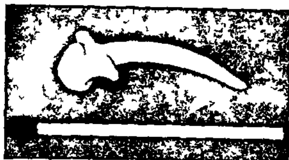


Figure 1 Ceramic endoprosthesis for the rabbit hip

Figure 2 X ray of rabbit hips with the ceramic endoprosthesis on the left ten days after the replacement operation

ranged from 2 to 8 months The study was based on clinical radiological and histological examinations the contralateral hip joint serving as control

The experimental animals stood the operation well under intravenous Nembutal anaesthesia and moved freely on the day after the operation and during the follow up period The range of movement of the hip joint was good On X rays practically no reaction was seen around the endoprosthesis (Figure 2) According to the histological examinations the endoprosthesis was surrounded in the femur by bony tissue without any giant cells or signs of infection Ceramic showed firm tissue adherence with bone growth adjacent to the stem without interposition of

soft tissue This suggests good tissue tolerance and biological inactivity of the ceramic material

LASEGUE S SIGN IN PATIENTS WITH LUMBAR DISC HERNIATION

Erik Sprangfort (Umeå and Harnosand Sweden)

The author has performed a complete analysis of 2 504 lumbar disc operations by automated data processing The study comprises approximately 50 variables per operation

This report is a survey of information obtained on Lasègue s sign or the straight leg raising test

In 2 157 patients with confirmed lumbar disc herniation Lasègue s sign was positive in 96 8 per cent The incidence of the sign decreases with the level of herniation in the cranial direction

When the sign is correlated to the age at operation the incidence decreases constantly with age The negative correlation to age is repeated in both positive and negative operations (Figure 1) in both sexes and at both the common levels (L4–L5 and L5–S1)

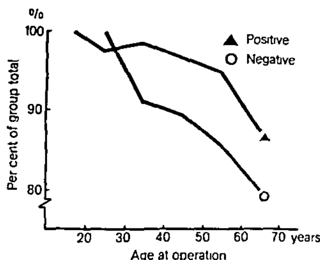


Figure 1 The incidence of Lasègue s sign by age and findings at operation

The specific diagnostic value of the sign is estimated in Figure 2 Young patients have a pronounced propensity for a p sitive reaction to straight leg raising and the sign has no specific value for the diagnosis of lumbar disc herniation However a negative Lasègue excludes the diagnosis with a high degree of probability in these age groups After the age of 30 the Lasègue propensit decreases and the diagnostic value of the sign increases but a negative Lasegue no longer excludes the diagnosis

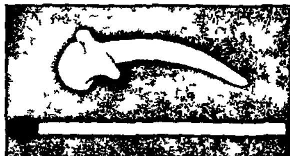


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Figure 2 X ray of rabbit hips with the ceramic endoprosthesis on the left ten days after the replacement operation

ranged from 2 to 8 months The study was based on clinical radiological and histological examinations the contralateral hip joint serving as control

The experimental animals stood the operation well under intravenous Nembutal anaesthesia and moved freely on the day after the operation and during the follow up period The range of movement of the hip joint was good On X rays practically no reaction was seen around the endoprosthesis (Figure 2) According to the histological examinations the endoprosthesis was surrounded in the femur by bony tissue without any giant cells or signs of infection Ceramic showed firm tissue adherence with bone growth adjacent to the stem without interposition of

soft tissue This suggests good tissue tolerance and biological inactivity of the ceramic material.

LASEGUE'S SIGN IN PATIENTS WITH LUMBAR DISC HERNIATION

Erik Sprangfort (Umeå and Harnosand Sweden)

The author has performed a complete analysis of 2 504 lumbar disc operations by automated data processing The study comprises approximately 50 variables per operation.

This report is a survey of information obtained on Lasègue s sign or the straight leg raising test.

In 2 157 patients with confirmed lumbar disc herniation Lasègue s sign was positive in 96 8 per cent The incidence of the sign decreases with the level of herniation in the cranial direction

When the sign is correlated to the age at operation the incidence decreases constantly with age The negative correlation to age is repeated in both positive and negative operations (Figure 1) in both sexes and at both the common levels (L4–L5 and L5–S1)

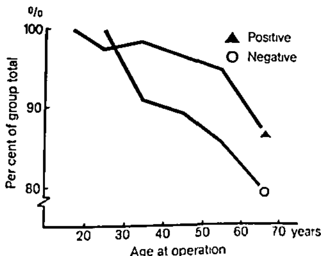
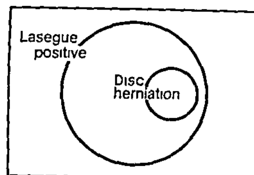
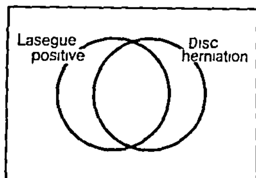


Figure 1 The incidence of Lasègue s sign by age and findings at operation

The specific diagnostic value of the sign is estimated in Figure 2 Young patients have a pronounced propensity for a positive reaction to straight leg raising and the sign has no specific value for the diagnosis of lumbar disc herniation However a negative Lasègue excludes the diagnosis with a high degree of probability in these age groups After the age of 30 the Lasègue propensity decreases and the diagnostic value of the sign increases but a negative Lasègue no longer excludes the diagnosis



Age under 30 years



Age over 30 years

Figure 2

KNEE AND QUADRICEPS FUNCTION AFTER FRACTURE OF THE FEMUR

Danilo Zdravkovic & William Damholt (Odense Denmark)

75 patients were investigated for knee flexion difference in circumference of the thighs and had isometric and dynamic measurement of quadriceps strength The follow up period ranged from 3–13 years Over two thirds showed a more than 20 per cent reduction of quadriceps strength There was little correlation between the wasting of the thigh and the reduction of strength Measurement of quadriceps strength is considered a relevant parameter in the follow up of patients with fracture of the femur

HEALING OF AVASCULAR ARTICULAR FRAGMENTS AN EXPERIMENTAL STUDY ON THE CANINE KNEE JOINT

Anders Wigren & Sven Olerud (Uppsala Sweden)

The union of avascular articular fragments in the knees of adult dog was studied by fluorescence microscopy after tetracycline and fluorescein labelling and

by microangiography after filling with Indian ink. In the knee joints avascular fragments of the tibial condyle were fixed by stable osteosynthesis The course was compared with that of joints allowed to move freely and joints immobilized in plaster It was not possible to demonstrate any difference between the bony union in the two groups Union of the avascular fragment takes place by direct bone formation without any difference between the immobilized dogs and those that were allowed to move freely

On the other hand the dogs in plaster showed on the whole an increased in growth of vessels into the articular cartilage from subchondral bone In some cases the surface of the cartilage was even invaded by vessels proceeding through the osteotomy gap These changes were not found in dogs allowed to move the knee during the experiment

DIAGNOSTIC POSSIBILITIES OF DOUBLE CONTRAST ARTHROGRAPHY IN DISORDERS OF THE KNEE

Henrik Schmidt (Nykøbing F Denmark)

Since 19?1 double-contrast arthrography has been used in the Radiological Department of the Central Hospital Nykøbing Falster Denmark, as a preoperative investigation in various disorders of the knee The experience from 102 examinations confirmed by operation in all cases has been so encouraging that we want to call attention to this method as a valuable contribution to diagnosing internal derangement of the knee joint The examinations were done by a modification of van de Berg & Crevecoeur s method under fluoroscopy with image amplifier and TV using a double magnification as recommended by Croonenbergs & Rombouts as well as Zakrisson & Thoms The examinations comprise serial exposure of each meniscus separately general views in two projections special exposures to visualize the cruciate ligaments and axial exposures of the patella in Knutson s projection The following disorders may be diagnosed with fair certainty by double-contrast arthrography

1 Injuries to the menisci
2 Injuries to the cruciate ligament
3 Injuries to the collateral ligament
4 Loose bodies (in the joint cavity and chondromatosis)
5 Osteochondritis dissecans
6 Patellar chondromalacia
7 Other destructions of cartilage
8 Hoffa s disease

There have been no complications to the investigations The operations were already performed on the day after the X ray examination

A total of 10 erroneous diagnoses were made (9 8 per cent) relating to meniscus injuries 5 positive and 5 negative On Dijan s recommendation we have directed our attenti n particularly at the articular cartilages and we feel that we are able to diagnose o teoarthritis even before osseous changes appear

TIBIAL CONDYLAR FRACTURES WITH A PARTICULAR VIEW TO THE VALUE OF TOMOGRAPHY

Gunnar Schiøler (Copenhagen, Denmark)

In view of the importance of an accurate radiological diagnosis to the operative indication in treating tibial condylar fractures the results of conventional radiography were compared with those of tomography in 65 depression fractures. The degree of depression will be seen in Table 1.

The value of tomography was illustrated by typical examples.

Table 1. Number of fractures

Depression in mm	0–3	4–10	more than 10
Conventional radiography	31	23	11
Tomography	15	22	28

The value of tomography was illustrated by typical examples.

At follow up all the patients had tomography. We feel that there is a relationship between an unsatisfactory functional result and major secondary osseous defects comprising the marginal parts of the joint surface. The size of these defects cannot be assessed without tomography.

It is concluded that examination and assessment of tibial condylar fractures are incomplete without tomography.

DISCUSSION

Bent Barfod (Århus, Denmark)

Tomography is indicated to establish whether a fracture is present and partly to map the displacement of a known fracture. In traumatic haemarthron where a fat level is demonstrable radiologically or as fat pearls in the aspirate tomography should always be carried out with ½ cm sections in order to detect the fracture which is bound to be present.

Postoperatively tomography of the knee should be performed with the same care as preoperatively to evaluate the result. Otherwise one is fooling oneself.

X RAYS OF THE LUNGS IN DIAGNOSING TRAUMATIC FAT EMBOLI

Knud Tophøj (Sorø, Denmark)

Six cases of traumatic fat embolism occurred in patients admitted to the Hospital for Orthopaedic Surgery, Sorø, Denmark, during the period 1965–1968. All the patients had one or multiple fractures sustained in road accidents.

The diagnosis of fat embolism was based upon the presence of tachycardia, tachypnoea, and hyperpyrexia as well as upon changes on X rays of the lungs,

consisting in multiple small, diffuse bilateral lesions These radiological appearances were present in all the cases

On the basis of a post mortem histological investigation of pulmonary tissue from two out of the six patients I believe that scattered interstitial haemorrhages in the lungs cause the typical radiological appearances This is also indicated by the fall in haemoglobin seen in cases of fat embolism The radiographic changes subside in a week or two

Patients who may be feared to develop traumatic fat emboli ought to be checked frequently by pulse and respiration counts and measurement of the temperature If these values rise I recommend chest radiography e g at six hour intervals to confirm the diagnosis

When the typical changes are found the patient should be transferred to an intensive observation unit A fall in oxygen saturation or an increase in the pCO_2 indicates tracheostomy and artificial respiration Thereby deep coma in one of the patients was altered to a normal level of consciousness in three hours

STABILITY OF LOWER LEG FRACTURES TREATED BY HOFFMANN S OSTEOTAXIS

Torben Ejsing Jorgensen (Beder Denmark)

A mechanical method of measuring the stability of lower leg fractures in combination with Hoffmann s apparatus is described

The method was applied to 40 lower leg fractures At the measurements the fractures were loaded by a bending factor of 5 kg on a 10 cm long arm on both sides of the neutral point The resulting angle was measured If quiet walking is to be tolerated this angle must not exceed 2–1

The method was used for graphic description of the last part of the union of lower leg fractures This revealed among other things that minor traumas to lower leg fractures during union delayed the union The length of this delay could be estimated The method makes it possible to establish the time of union and prognosis during the terminal phase of union

CONTINUED EXPERIENCE OF LINCOCIN

Bernhard Paus (Sandvika Norway)

Lincocin has been used for some 3½ years in the treatment of chronic pyogenic osteomyelitis acute osteomyelitis pyogenic arthritis and soft tissue infection The results of 97 courses are reported Follow up period 6–36 months after relief of symptoms

Out of 58 patients with chronic osteomyelitis 51 were relieved of symptoms, but 11 relapsed 8 of the latter patients had another course after which 7 were relieved of symptoms Out of the 7 patients whose symptoms and signs did not yield 4 had Lincocin insensitive microorganisms All of them were relieved of their *Staph aureus* and considerably improved clinically but the infection by other micro organisms persisted. The remaining 3 h d Lincocin resistant microorganisms In 2 of these cases it is possible that the staphylococci changed from sensitive to resistant

Table 1

Dog no	Weight in kg	Sex	Date of operation	Survival in days	Date of sacrifice	Date of tetracycli… injection (25 mg … body weight)	
950	21	♂	10-3-69	10	21-3-69	20-3-69	
1016	19.4	♂	11-4-69	34	16-5-69	15-5-69	
1011	28.7	♀	11-4-69	40	22-5-69	21-5-69	
1000	17.3	♂	28-3-69	59	27-5-69		
996	22.5	♀	28-3-69	61	29-5-69	28-5-69	
939	16.2	♀	12-3-69	88	9-6-69	5-6-69 9-6-69	½ week
943	18.3	♂	17-3-69	91	17-6-69	10-6-69 17-6-69	1 week
934	15.1	♀	2-4-69	91	3-7-69	2-6-69 2-7-69	4 week…
949	20.8	♂	17-3-69	98	24-6-69	10-6-69 23-6-69	2 week…
974	14.7	♀	24-3-69	104	7-7-69	10-6-69 6-7-69	4 week…
962	19	♂	19-3-69	105	3-7-69	10-6-69 2-7-69	3 week…
971	[illegible]5	♀	2-4-69	109	22-7-69	2-6-69 21-7-69	7 week…

The operation was performed on the right femur in all cases X rays of both femurs were obtained before and after the operation

The right gluteal region was shaved washed and painted with iodine and then draped with sterile towels leaving the area over the right greater trochanter uncovered

In the skin over the greater trochanter an incision of 4 cm was made parallel to the length of the bone this was followed by direct dissection down to the bone A subtrochanteric defect was made in the cortical bone by chiselling out a flap of 2 × 1 cm The medullary cavity was not drained by suction and curetted the structure of the spongiosa in the trochanteric region was left intact

A teflon tube of suitable diameter was then introduced through the defect after being connected to the cylinder of a metal syringe The tube was passed down as far distally as possible

After preparing the acrylic cement and connecting the metal syringe the cement was packed into the medullary cavity By gradual withdrawal of syringe and tube while the screw spindle was turning the entire intramedullary cavity was filled After this procedure the bone flap was restored to its original position and the wound was closed in layers

All surgical wounds healed *per primam* One week after the operation all dogs showed a normal pattern of locomotion

During the interval between operation and death no complications were observed

except in dog no 1000 which died from unknown causes two months after the operation Histological examination of this dog's femur disclosed osteomyelitis This dog was excluded from this study

Preparation of Dogs for Histological Examination

All dogs were given tetracycline intravenously (Table 1) so as to ensure that an impression of the degree of ossification and osteogenesis could be gained at a given time from the calcification fronts demarcated by the tetracycline The tetracycline used was oxytetracycline hydrochloride (Pfizer) The dosage was 25 mg/kg body weight

After sacrificing the dog by intravenous injection of an overdose of pentobarbital sodium (Nembutal 1–3 ml) the two femurs were dissected out

After obtaining X rays of both femurs the femoral diaphyses were cut into transverse discs of about 1 cm thickness which were numbered from the proximal to the distal end Every other disc was fixed in buffered formalin the remaining discs being fixed in absolute ethyl alcohol

The formalin fixed discs were decalcified in a solution of ethylene-diamine tetra acetic acid and embedded in paraffin whereupon sections of 7 μ thickness were cut and stained with haematoxylin eosin

The alcohol fixed discs were embedded in methyl methacrylate plastic whereupon sections of 80 μ thickness were cut out These sections were not stained

The dogs numbered 939 943 934 949 974 962 and 971 were given two injections of tetracycline the interval between the two injections being one half one four two four three and seven weeks respectively This made it possible to gain a good impression of the degree of osteogenesis during the interval between the injections

RESULTS

Radiological Findings

X rays of all treated femurs were obtained immediately after the operation All these X rays showed that the cement filled three quarters of the medullary cavity contact with the endosteal wall of the cortical bone was good throughout the length of the cavity

The first visible changes were observed after 34 days in dog no 1016 irregularly bounded subperiosteal bone apposition which was maximal halfway the length of the diaphysis and gradually diminished in proximal and distal direction No distinct structure was recognizable in this appositional bone The apposition layer was 5 mm thick As compared with the control femur the cortical bone structure did not have its normal structure (Figure 1 A)

Sixty one days after the operation the subperiosteal apposition was found to have substantially increased throughout the length of the diaphysis The thickness halfway the diaphysis was 10 mm diminish-


A
84 d
B
C
99 d
D
105 d

ing in proximal and distal direction The cortical bone structure was vague with areas of rarefaction (Figure 1 B)

The features observed after 88 and after 91 days were identical to those found after 61 days but circular bone apposition was unmistakably decreased Maximal thickness halfway the diaphysis was 4 mm

After 98 days (do, no 949) only moderate subperiosteal bone apposition remained with bone densifications in longitudinal direction The wall of cortical bone was broadened in comparison with the control femur and showed rarefactions alternating with densified structures (Figure 1 C)

After 105 and 109 days X rays showed a slight periosteal bone reaction with a maximum halfway the diaphysis The wall of cortical bone showed a less dense structure (Figure 1 D) All radiographs showed that contact between acrylic cement and endosteal wall of cortical bone had been maintained

Macroscopic Findings

Macroscopic examination of the dissected femurs revealed that the radiologically established periosteal bone apposition was clearly visible (Figures 2 A B) This tissue proved to be of hard consistency The features of the periosteal tissue were normal in all cases

In two cases cement distributed in the muscle-tissue was encapsulated by connective tissue The original site of the surgical femur defect could be traced only with difficulty it was concealed from view by periosteal bone apposition

Once the treated femur had been cut into transverse discs of 1 cm

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Figure 1 A No 1016 Röntgenogram of left control femur and right treated femur Note the subperiosteal apposition of bone in the mid portion of the right femur shaft

Figure 1 B No 996 Röntgenogram of left control and right treated femur 61 days after operation The subperiosteal apposition is more profuse and extensive

Figure 1 C No 949 Rontgenogram of left control and right treated femur 98 days after operation The bone apposition is decreased and the cortical wall shows rarefactions alternating with dense structures

Figure 1 D No 962 Röntgenogram of control femur at the right and treated femur (left) 105 days after operation Note the slight subperiosteal bone apposition The structure of the cortical wall shows a spongeous character

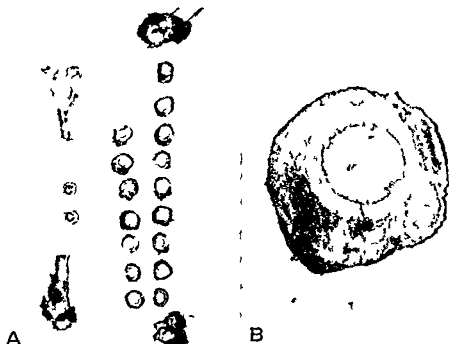


Figure 2 A No 1011 Macroscopic picture of a treated femur (rt) 40 days after operation The maximum of the subperiosteal bone formation is situated in the mid portion of the femur shaft The control femur at the left Figure 2 B shows the enlargement of a transverse bone section The acrylic cement lies in the centre The callus formation lies around the pre existent corticalis

thickness the cement was found to be very firmly adherent to the endosteal wall of the corticalis

DISCUSSION

The most conspicuous feature of all treated femurs was the increase in diameter resulting from circular subperiosteal bone apposition In all cases this apposition extended throughout the length of the diaphysis In this experiment it was first observed after 34 days reached a maximum after 61 days and gradually diminished to a minimum after 105 days

It is considered plausible that the first radiological changes become visible between the 10th and the 34th postoperative day

The same proliferative appositional bone formation has been described in the experiments of Frueta & Lavadias (1955) Rietz (1968) and *Danckwardt Lilliestrom (1969)*

It is of importance to note that the pre existent cortical bone shows radiological structural changes After 34 days the cortical bone shows some blurring and even partial effacement whereupon a cortical bone structure gradually becomes visible in which local rarefactions are seen Finally the corticalis has a spongeous structure

In the course of the experiment the impression was gained that the subperiosteal apposition primarily occurs halfway the length of the diaphysis the proximal and distal portions of the femur are not involved in the process until later The intensity of the periosteal reaction too was always found to be higher halfway the diaphysis than in the proximal and distal portions

No radiological changes were seen in the acrylic cement in the course of the experiment It retained its firm contact with the endosteal site of the corticalis This mechanical bonding between acrylic cement and bone has been described in the experiments of Henrichsen Jansen & Krogh Poulsen (1951)

CONCLUSIONS

After complete filling of the femoral medullary cavity with acrylic cement macroscopic and radiological osseous changes were observed in dogs

The diameter of the femur increased as a result of circular subperiosteal apposition—a reaction which attains its maximum about 60 days after the operation and then gradually diminishes This reaction shows a maximum both in time and in place In all treated femurs the maximum reaction was localized halfway the length of the diaphysis

In addition to osteogenesis there were structural changes in the appositional bone as well as in the pre existent cortical bone

No radiological changes were observed in the acrylic cement which retained its contact with the endosteal wall of cortical bone throughout the experiment

HISTOLOGICAL STUDY

Bone discs of about 1 cm thickness marked A C E etc were decalcified embedded in paraffin and cut into sections The discs marked B D F etc were embedded in plastic and cut into sections Control sections were obtained from the untreated (left) femur The follow

ing are the principal findings obtained by histological examination of these series of sections

No 950 (10 Days After Operation)

An incipient subperiosteal bone apposition is present which in view of the comparative levels of the sections has its maximum halfway the length of the diaphysis More proximal and distal levels show hardly any periosteal reaction

Halfway the length of the diaphysis there is necrosis of the endosteal aspect of the cortical bone manifested by absence of tissue structures in the haversian canals The osteocyte nuclei are still present

The plastic embedded section shows occasional tetracycline markings on the periosteal side of the cortical bone around the marrow canals, this finding is suggestive of local osteogenesis The endosteal side is covered by some granulation tissue without foreign body reaction

No 1016 (34 Days After Operation)

Halfway the length of the diaphysis the subperiosteal bone apposition—already existing after 11 days—has become more extensive A sharp demarcation is seen between the subperiosteal apposition and the pre existent cortical bone (Figure 3) The necrosis of the cortical bone (endosteal side) is even more apparent in that the majority of the osteocytes have disappeared from the lacunae

The tetracycline marking shows that the ossification around the subperiosteal canals—already noted after 11 days—is increasing In this series of sections, too the intensity of the processes is maximal

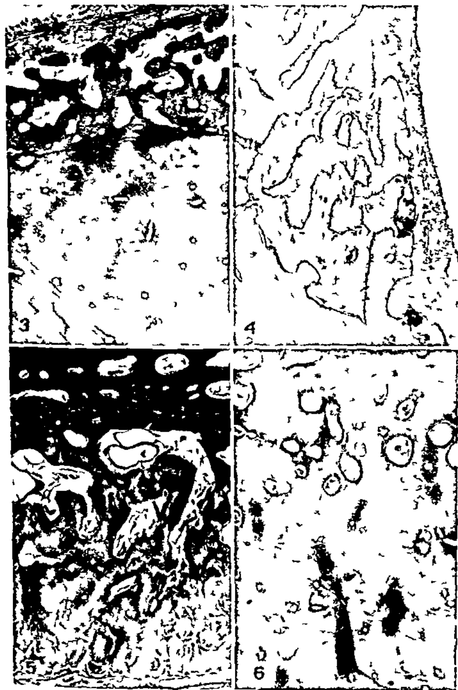
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Figure 3 (40 ×) No 1016 Histological appearance of a section of a treated femur 34 days after operation A sharp demarcation is seen between the subperiosteal callus formation and the necrotic area in the corticalis

Figure 4 (40 ×) No 1011 Histological appearance of an area endostally situated 40 days after operation Adjacent to necrotic areas in the corticalis islets of active osteogenesis are seen

Figure 5 (40 ×) No 996 In the subperiosteal layer signs of maturation are observed 61 days after operation The lacunes are invaded by newly formed cells

Figure 6 (40 ×) No 996 The osteoblast activity is directed from subperiostally to endostally


3
4
5
6

halfway the length of the diaphysis and diminishes in proximal and distal direction

No 1011 (40 Days After Operation)

These sections show the same feature as those of no 1016 but on the endosteal side of the cortical bone virtually all osteocytes have disappeared indicating the spread of necrosis Adjacent to the medullary cavity a layer of delicate collagenous tissue without foreign body giant cells is forming on the endosteal surface of the cortical bone Beneath this layer endosteal osteogenesis is taking place at the sites of rarefaction in the cortical bone (Figure 4)

No 996 (61 Days After Operation)

The already described periosteal bone apposition is showing signs of maturation Unmistakable osteoblast activity is observed in the subperiosteal cortical regions This activity spreads in endosteal direction around revascularized marrow canals (Figures 5 and 6)

No 939 (88 Days After Operation)

Increasing maturation of sub periosteally formed bone and ossification in subperiosteal areas of the cortical bone At the boundary between the endosteal cortical bone and the space which has accommodated the acrylic cement a layer of connective tissue has formed in which foreign body cells are observed (Figures 7 and 8)

No 943 (91 Days After Operation)

Subperiosteally the apposition bone locally assumes the features of cortical bone tissue The thickness of the apposition bone is evidently less than in the sections of No 939

Figure 7 (40 ×) No 939 Foreign body giant cells around spaces which were filled with acrylic cement 88 days after operation

Figure 8 No 939 250 × enlargement of foreign body giant cells

Figure 9 (40 ×) No 943 Histological appearance of dilated haversian canals in the pre existent corticalis 91 days after operation

Figure 10 ([illegible] ×) No [illegible] Enlargement of a spongeous area Note the connective tissue membrane


7


8


9


10

Osteogenesis is taking place throughout large subperiosteal cortical areas and also at various sites in the endosteal cortical bone Double tetracycline markings are observed around the canals in the subperiosteal layer in the endosteal layer only a single band encircles the canals The distance between the two bands (subperiosteally) provides a measure of the amount of bone newly formed during the intervals between the two tetracycline injections In this case the interval was one week (see Table 1)

The fact that only one tetracycline band is visible in the endosteal layer indicates that osteogenesis in this region did not start until after the first tetracycline injection

No 934 (91 Days After Operation)

The features are identical to those in no 943 but it is conspicuous that the haversian canals in the pre-existent cortical regions throughout the femur are dilated spongy alteration of the cortical bone (*Figure 9*)

Throughout the transverse section the cortical bone shows tetracycline marking around the haversian canals Particularly on the subperiosteal side there are double bands the distance between which corresponds with the interval between the two injections

No 949 (98 Days After Operation)

As compared with no 934 more advanced maturation of subperiosteal bone apposition and spongy alteration of the cortical bone Osteogenesis extends into the endosteal areas

No 974 (104 Days After Operation)

A striking feature of these sections is the presence of double tetracycline bands around the marrow canals extending into the endosteum The distance between these bands corresponds with a time interval of 4 weeks between injections

No 962 (105 Days After Operation)

The features are identical to those of the sections of no 974 The periosteal bone apposition is of limited thickness and shows evident maturation Matured bone is present also at some endosteal sites Necrotic marrow canals are no longer visible (Figure 10)

No 971 (109 Days After Operation)

The maturation of endosteal osteogenesis is further advanced as is the periosteal bone apposition The cortical bone shows a spongiosa structure dilatation of the medullary vessels The distance between the tetracycline bands in these sections is considerable corresponding to an interval of 7 weeks between injections

DISCUSSION

The study of the histological sections disclosed the following important features subperiosteal bone apposition partial necrosis of the cortical bone a foreign body reaction and gradual disappearance of the cortical necrosis

The subperiosteal bone apposition can already be observed after 10 days and the same applies to the cortical necrosis The latter remains confined to the innermost two thirds of the corticalis

Regeneration of the corticalis occurs from the periosteum and gradually extends throughout the cortical wall in the course of 109 days These regenerative processes from periosteal to endosteal regions are first observed after 61 days after which remodelling of the entire cortical bone takes place

The above mentioned reactions involve the entire length of the diaphysis

Similar findings have been reported by Trueta & Cavadias (1955 1964) Rietz (1968) and Danckwardt Lillieström (1969) Trueta & Cavadias (1955) ligated the femoral nutrient arteries in a series of dogs and introduced a Kuntscher nail into the medullary cavity in the next series Both procedures led to reversible necrosis of the inner two thirds of the cortical wall They also describe the subperiosteal bone reaction they believe that lesions of the femoral nutrient arteries cause the periosteal vessels to take over the vascularization of the bone which leads to subperiosteal osteogenesis

Rietz (1968) submitted dog femurs to segmental resection and restored continuity by means of a cemented metal prosthesis he observed periosteal bone apposition both in the group of the stable and in that of the unstable prostheses In the latter group however the degree of osteogenesis was significantly higher He mentions that periosteal activity diminishes after some time and that the cortical bone is remodelled in the course of the experiment Between the acrylic cement and the endosteal aspect of the cortical bone, D

demonstrated islets of osteogenesis as well as a connective tissue membrane of varying thickness containing foreign body giant cells

Danckwardt Lilliestrom (1969) reported in a detailed study on the periosteal cortical and medullary reaction following lesions of the nutrient arteries caused by curettage reaming and suction drainage of the femoral medullary cavity in dogs and rabbits He concluded that after total destruction of the nutrient arteries the blood supply to the entire cortical bone can be maintained by the periosteal vessels The latter responded to the operative procedure by dilatation and coiling He observed that the ischaemic necrotic cortical regions are revascularized from the hyperactive periosteal vessels and that the subperiosteal osteogenetic activity is increased

With a view to these publications on comparable experiments we believe that the findings we obtained can be ascribed to lesions of the nutrient arteries caused by the operative procedure the passage of a teflon tube and subsequent packing of the medullary cavity with acrylic cement In addition we regard it as likely that this procedure leads to an increase in intramedullary pressure which may give rise to the formation of a so called medullohaematoma (Zuckman 1968) and massive fat embolism (Danckwardt Lilliestrom 1969 a 1969 b)

In one of the experiments carried out by Danckwardt Lilliestrom embolus formation and increase of pressure were reduced by suction drainage of the medullary cavity before and during the operative procedure The avascular region in the cortical bone was thus markedly reduced

We confirmed this observation in a series in which the medullary cavity was drained by suction and only partly packed with cement reducing the increase in pressure and the damage to the nutrient arteries subperiosteal bone apposition did not occur in this series (in press)

Apart from this mechanical factor the thermal reaction must be mentioned as a second cause of the cortical necrosis The polymeriza tion heat of the acrylic cement used is mainly dependent on the amount of cement introduced (Ohnsorge Kroesen 1969 Ohnsorge Goebel 1969 Charnley 1970) We did not measure the temperature but believe that it must have been high in view of the large amount of cement intro duced (10–12 ml)

The exact contribution of each of the two causes to the bone reac tions described has not been established We did demonstrate how ever that an unmistakable tendency toward restoration of the is

chaemic necrotic cortical region occurred after some time the process developing from the periosteal to the endosteal aspect

We were unable to demonstrate a permanent sharp line of demarcation between the necrotic cortical bone and the vital subperiosteal cortical bone We observed that the regenerative process—the reconstruction of the cortical bone—invaded the endosteal cortical bone from the periosteal aspect after about 60 days

With advancing regeneration and revascularization the subperiosteal apposition diminishes and the pre existent cortical bone assumes a spongiosa structure (after 91 days) After 109 days most of the ischaemic necrotic cortical bone is regenerated At that time restoration is nearly complete

After a few weeks a delicate collagenous connective tissue layer is formed between cement and endosteal cortical bone in all sections described this layer closely followed the configuration of the bone surface It seems probable that the space between bone and cement is filled up by this connective tissue This means that it is not of the same thickness throughout but shows local thickening defects in the cortical bone being filled by endosteal osteogenesis (Schenk Willenegger Bandi 1966 Rietz 1968 Boitzy 1969 Charnley 1970) Foreign body giant cells were found in this connective tissue layer after 88 days

This finding is in agreement with data from the literature (Henrichsen et al 1951 Debrunner 1953 Muller 1962 Huggler 1968 Willert Schreiber 1969 Charnley 1970) No necrosis or inflammatory reactions were observed near these giant cells

Finally it should be pointed out that new bone—tetracycline marked osteons and trabeculae—is forming itself in the immediate vicinity of the acrylic cement

CONCLUSIONS

Packing of the entire femoral medullary cavity with acrylic cement in dogs led to partial necrosis of cortical bone associated with subperiosteal bone apposition Both reactions were reversible and their principal cause was probably damage to the nutrient arteries In view of the large amount of cement introduced thermal damage may also have been involved

The ischaemic necrotic cortical bone was gradually regenerated by revascularization from the subperiosteal aspect this process was first observed in the series of sections after 61 days and was extended to the endosteum of the corticalis after 109 days

On the endosteal side of the cortical bone a layer of connective tissue of varying thickness developed in which foreign body giant cells were observed

No inflammatory reactions were seen in the vicinity of the acrylic cement It can be stated that within the time limits of this experiment we observed no permanent harmful influence of the acrylic cement and the operative procedure on the bone tissue

SUMMARY

This paper describes an animal experiment made in order to study the influence of acrylic cement on the bone tissue at different intervals of time introduced into the medullary cavity

The most conspicuous reaction to complete cementing of the femoral medullary cavity was radiological evidence showing a circular increase in bone diameter due to apposition of newly formed bone in which structural changes occurred in the course of 10 till 109 days after operation

Macroscopic examination of the various bone discs showed that the cement remained very firmly attached to the inferior cortical wall

Histological examination disclosed transient partial necrosis in the pre-existent corticalis and subperiosteal bone apposition Where the cement had touched the inferior cortical wall a connective tissue membrane of various thickness had been formed Foreign body giant cells were formed in this membrane No inflammatory reactions were observed After some time there was regeneration of the ischaemic necrotic areas in the corticalis a process developing from the periosteum to the endosteum

It must be considered probable that the bone reactions observed were caused by damage to the nutrient arteries

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Yale University School of Medicine Section of Orthopaedic Surgery
New Haven Connecticut U S A and
Department of Orthopaedic Surgery Karolinska Institute Stockholm Sweden

AN EXPERIMENTAL STUDY OF THE IMMEDIATE LOAD BEARING CAPACITY OF SOME COMMONLY USED ILIAC BONE GRAFTS

Augustus A White III & Carl Hirsch

Accepted 29 ix 1971

Orthopaedic and other reconstructive surgeons employ different configurations of bone grafts to provide a stabilizing function in fusions of the cervical and lumbar spines Knowledge of the relative strength of the different types of bone grafts is of interest to the surgeon The authors are not aware of any investigations of the load bearing capacity of the different popular configurations of bone grafts

Three commonly used grafts are investigated in this study (a) the horseshoe type employed by Smith (1958), Robinson (1955) and Southwick (1961) (b) the dowel type employed by Cloward (1958 1965) and (c) a modification of the strut type employed by Bailey & Badgley (1960) A brief review of the mechanical use of these grafts (Figure 1) will show that in the immediate postoperative period the strength and stability of the surgical construction is largely dependent on the capacity of these bone grafts to withstand vertical compressive loads It has been noted that some mechanical designs of anterior bone grafting tend to collapse (Kebish & Keggi 1967) or may be unstable (Simmons & Bhalla 1969) A study of the load bearing capacity of entire constructs is planned This preliminary study is presented to give information about the relative strengths of these different grafts and the range of forces that they can withstand It was decided to examine the load bearing capacities of these various grafts under controlled experimental conditions which would provide useful information and allow meaningful comparisons among them

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This investigation was supported by the Yale University School of Medicine Section of Orthopaedic Surgery the National Institute of Health Orthopaedic Training Grant and Swedish State Research Board Grant #B71-17X-565-07

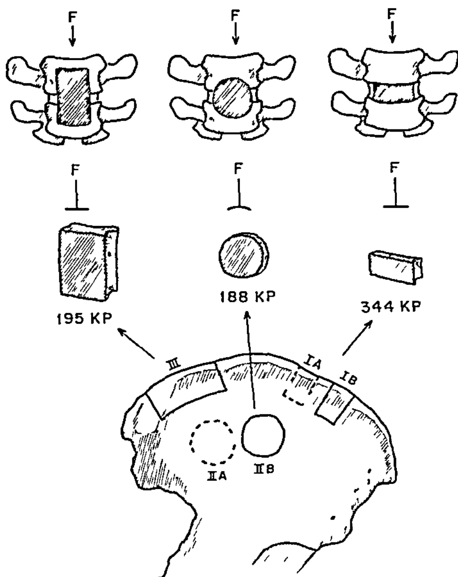


Figure 1 Diagram of approximate location from which grafts were taken the manner in which they were loaded and their characteristic location in the fusion The figures are the average of the failure points for the three general types

MATERIAL

The grafts were taken at autopsy from ten subjects five males and five females with an age range from thirty three to eighty five years None of the ten subjects had diseases known to affect bone

Preparation of Material

During autopsy either the right or the left ilium of the subject was removed and stored at minus twenty five C. There is evidence that freeze storing does not affect the physical properties of bone (Evans 1957 Sedlin & Hirsch 1966) At the time of testing the grafts were prepared as described below The horseshoe type graft hereafter to be referred to as *type I a* or *I b* was prepared as follows With a double blade oscillating saw set with seven to ten millimeters between the blades two *type I* grafts were cut as shown in Figure 1 These grafts were all in

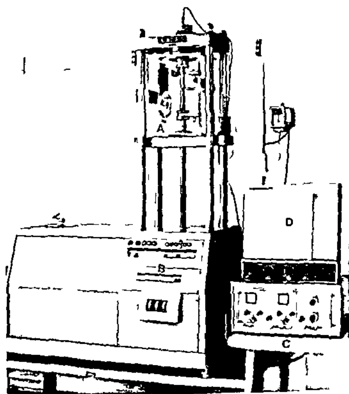


Figure 2 Photograph of experimental apparatus shows (A) testing chamber (B) Alwetron test machine (C) amplifiers and (D) x y recorder

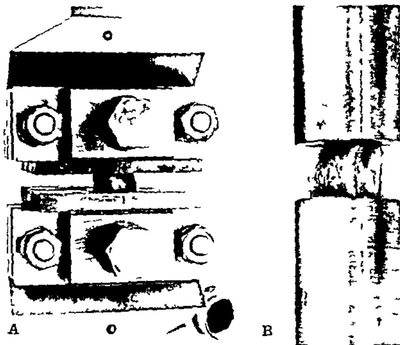


Figure 3 (a) Photograph of the clamps and plates employed to load types I and III (b) Special cylinders employed to load type II

the range of nineteen to twenty five millimeters on their long axis *I a* was taken anterior to *I b* The grafts were placed in Ringers lactate solution at room temperature

The dowel grafts which are designated *II a* and *II b* were taken in the following manner An oscillating Cloward dowel saw with a sixteen millimeter inside diameter was employed to take two grafts from the ilium in the area indicated in Figure 1 In this case also *II a* was taken slightly anterior to *II b* and the two pieces of bone were placed in Ringers solution at room temperature

The strut graft called *type III* was taken with the two blades of the oscillating saw twenty to twenty two millimeters apart (Figure 1) Its size in the axis that corresponds to the long axis of *type I* is also nineteen to twenty five millimeters This graft was also placed in Ringers solution at room temperature

Experimental Apparatus

The experimental apparatus included a T-2000 Alwetron testing machine an amplifier and a Hawlett Packard Moselev recorder model AM 7001 or AM 7030 (Figure 2) Flat testing plates were used to test *type I* and *III* grafts (Figure 3 a) and a specially constructed half circle connector was employed to test *type II* grafts (Figure 3 b)

MATERIAL

The grafts were taken at autopsy from ten subjects five males and five females with an age range from thirty three to eighty five years None of the ten subjects had diseases known to affect bone

Preparation of Material

During autopsy either the right or the left ilium of the subject was removed and stored at minus twenty five C. There is evidence that freeze storing does not affect the physical properties of bone (Evans 1957 Sedlin & Hirsch 1966) At the time of testing the grafts were prepared as described below The horseshoe type graft hereafter to be referred to as *type I a* or *I b* was prepared as follows With a double blade oscillating saw set with seven to ten millimeters between the blades *two type I* grafts were cut as shown in Figure 1 These grafts were all in

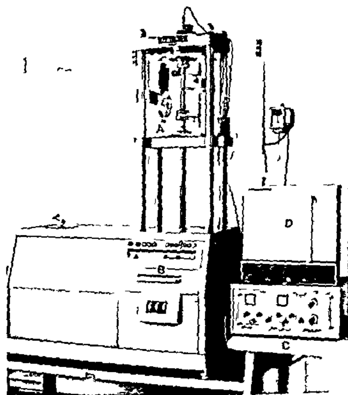


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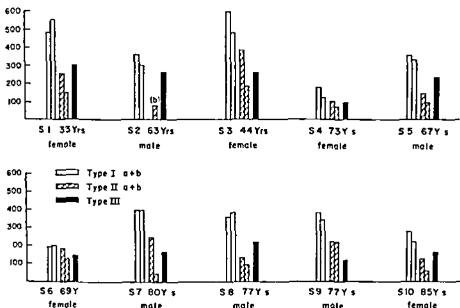


Figure 5 Histogram of failure point in kiloponds for the different types of grafts

failure point is reported in kiloponds Kilopond (kilogram force or kilogram weight) is defined as a force in any direction of 9 80665 newtons The force of a kilopond is equivalent to the weight of one kilogram mass under standard earth gravity (Cochran 1971) The values obtained are in Table 1 The histograms show comparisons of the values for the individual subjects (Figure 5)

1 The two younger specimens tended to be stronger than the older ones
2 The failure point for *type I* was higher than for *type II* and *type III* Statistical evaluation employing a two way classification and analysis of variance showed this statement to be significant at the 01 level of confidence (Ruff 1950)
3 *Type II a* tended to have a higher failure point than *type II b* This is significant at the 10 level of confidence

DISCUSSION

In this study we have sought to provide an answer to the question Given a particular patient s ilium which of the three commonly employed configurations of bone grafts would withstand the greatest

compressive load? The manner of loading in this experimental situation does not simulate exactly the type of loading that the graft undergoes clinically It is reasonable to assume however that the major vector of force in the clinical situation is that of vertical compression as diagrammed in Figure 1 Consequently the end point or failure point that was chosen was considered the best objective indication of the strength of the graft configuration Based on the findings here it seems a justifiable interpretation that the *type I* graft is most suitable for withstanding vertical compressive loads in the orientation in which these grafts were tested

A striking outcome of this investigation was the discovery of the very high vertical load tolerances of these configurations of bone This study has shown that prior to the time that the graft is acted upon by any biological processes they can bear sizable loads The range for the averages for these specimens was approximately 2 5 to five times the average body weight Calculations based on publications by Ruff (1950) and Henzel et al (1968) estimate the weight in a seventy kg man to be 6 3 kg above the first thoracic vertebra and 33 kg above the twelfth thoracic vertebra The high tolerance ranges observed suggest that the graft configuration itself may not be the weak point in the system certainly not in the early postoperative period The weakness lies in the over all mechanical construct consisting of the graft its associated vertebrae and the manner in which the vertebrae are changed to accept the graft

It is of interest to note that a good quantity of this strong bone came from aged individuals The average for the group was 66 8 years The specimens from the two younger subjects (1 and 3) were found to be stronger as might be expected (Lindahl & Lindgren 1968)

The follow mechanical consideration should be included It can be appreciated that the *type I* and the *type II* grafts were essentially the same in cross section dimensions and that they were loaded in the same orientation relative to these dimensions These tests show however that the longer *type III* grafts fail at a lower load (average 195 kiloponds) than the *type I* grafts (average 344 kiloponds) If these similar configurations of grafts are idealized as perfectly elastic homogenous rods different only in height (length) then elementary strength of material theory could be applied The phenomenon of the higher (longer) graft failing at the given lower point could be explained by an energy criterion of failure

The strong tendency for *II a* to be stronger than *II b* was probably

due to the observed slightly thicker anterior portion of the outer table of the ilium This finding indicates that if it is necessary to use a dowel type graft it should probably be taken from the more anterior portion of the ilium

SUMMARY

The strengths of three types of bone grafts were compared using the ilia from ten fresh autopsies The grafts were tested for their ability to withstand vertical compressive loads All three types were found to bear sizable loads The failure point in the horsehoe type grafts was significantly higher than the dowel type and the modified strut type grafts The findings are thought to have certain implications in the evaluation of the immediate postoperative mechanical charac teristics of different constructions for anterior spine fusions

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Department of Surgery Nilratan Sircar Medical College and Hospitals
Calcutta India

DYNAMIC STABILITY OF THE GLENOHUMERAL JOINT

A K Saha

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Stability of the glenohumeral joint during every phase of movement which is known as dynamic stability has not attracted the attention of anatomists (Saha 1967 1969) They were preoccupied with the stability of the glenohumeral joint in stance i e static stability

This paper attempts to clarify the factors responsible for dynamic stability The critical stage of dynamic stability of the glenohumeral joint is easily appreciated if we see an axial skiagram of the joint in 120 of abduction (Figure 1) Except for a small area most of the *articular surface of the head of the humerus is out of the socket and* anterior to the glenoid cavity (Saha 1967)

A shallow glenoid one third of the articular surface of the head of humerus in the normal adds to this precarious condition How in this critical stage which commences at 60 of abduction is the head of humerus retained in the glenohumeral joint?

Instability peculiar to the glenohumeral joint is mostly anterior to a less extent inferior and least posterior Injury is capable of dislocating any joint in any direction depending on the direction and degree of violence While this is true for the glenohumeral joint as well many of these are known to dislocate with minimum trauma or without any trauma as putting the hand in the sleeve of a coat while wearing it bowling doing the breast stroke while swimming changing position in sleep etc This instability has been seen to be anterior in these cases

Thus it is essential that we have a thorough understanding of the dynamic stability in various phases of movement and how this is affected in certain glenohumeral joints Dynamic stability is dependent on several factors (Editorial Indian J Surg 1967)



Figure 1 Axial view of the left gleno humeral joint in 120 of abduction shows most of the articular surface of the head of the humerus except a small area is anterior to the socket of the glenoid cavity

A Development of the Glenoid

Anthropometrically the state of development of the glenohumeral joint can be expressed as percentage ratios of the maximum transverse and vertical diameters of the articular surface of the glenoid and the head of the humerus (the latter with the help of caliper)

$$\text{Glenohumeral index} = \frac{\text{Maximum diameter of the glenoid}}{\text{Maximum diameter of head of the humerus}} \times 100$$

In the living this is not feasible Skiagraphy of the glenohumeral joint is taken in two directions antero posterior and axial views at right angles to each other in 120 abduction Maximum transverse and vertical diameters of the glenoid and the head of the humerus are computed from these skiagrams (Sarker 1969)

The development of the glenoid if falls above a certain level in transverse and vertical measurements adds to the stability The vertical and transverse glenohumeral indices were worked out from 50 normal shoulder joints of adults mostly drawn from the patients and staff of the N R S Medical College Hospitals Of these 34 were found to have a close distribution The remaining 16 were scattered on either side The mean value for vertical indices was 75 3 and that for transverse 57 6 The standard deviations were ± 3 9 for vertical and ± 5 6 for transverse glenohumeral indices If we include the extreme cases 75 3 ± 7 8 should be the vertical and 57 6 ± 11 2 the

transverse glenohumeral indices The data favourably compare with the anthropological data The transverse glenohumeral index which is less than the vertical plays an important role in the maintenance of horizontal stability while the vertical glenohumeral index plays a less important role Incidentally the transverse glenohumeral index is greater in primates e g gibbon The depth of the glenoid cavity in man is much less compared with that of the other primates This and increased transverse glenohumeral index have their role in maintenance of dynamic glenohumeral stability in primates specially where brachiation reached its maximum Gibbon is an example

B *Power of the Horizontal Steerers (Rotators)*

The glenohumeral joint is not a static fulcrum Radiological investigations in the living lamp black impression studies during simulated movements of dissected joints and theoretical considerations established that the contact surfaces of the humerus and to a much less extent that of the glenoid change with the movement confirming the joint's multiaxial nature

The physical process of change over of the articular surfaces of the humeral head in the glenoid is brought about by rolling These are movements taking place at the joint level and are distinct from classical movements (of the distal end) Rolling may be vertical and horizontal (Figures 2 & 3) (Saha 1950 1958 Saha et al 1956)

The power required for change over by rolling of the humeral articular surfaces in the glenoid is provided by subscapularis supraspinatus infraspinatus and upper half of teres minor in three directions the fourth being helped by gravity Their advantageous insertions at the outer end of head neck axis of the humerus are most suitable to control the rolling of the head This has been established mathematically from multilead electromyography in the normal surgically rehabilitated flail shoulder following poliomyelitis and in brachial plexus injuries where girdle muscles are used

In abduction those muscle fibres of the steerers (short rotators) which fall in the direction of elevation give coplaner rolling from the commencement of elevation This is confirmed by the simultaneous rise of the action potentials of deltoid and supraspinatus The remaining muscle fibres help horizontal rolling for that particular movement This is obvious from the action potentials of infraspinatus and subscapularis only the rise is earlier in subscapularis and later in infra

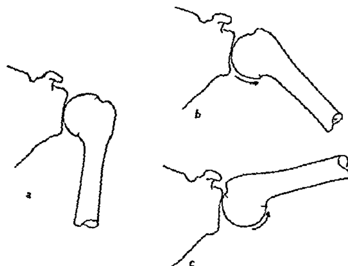


Figure 2

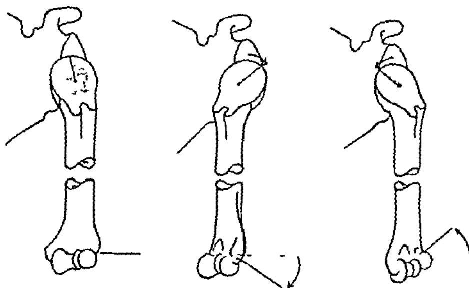


Figure 3

Figures 2 and 3 Diagramatical change over of the articular surfaces in vertical and horizontal directions by rolling

spinatus in abduction The resultant of these two components—horizontal and vertical in successive phase—give the consecutive positions of the actual path taken by the head of the humerus during elevation (Figure 4)

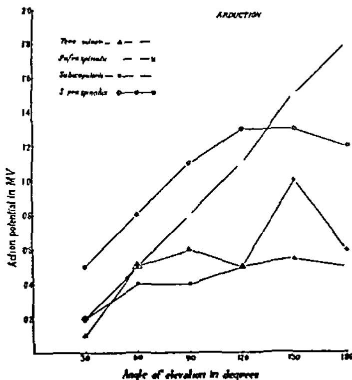


Figure 4 Simultaneous electromyograph of supraspinatus subscapularis infra spinatus and teres minor Ordinate represents the action potential in milli volts and the abscissa the angle of abduction in degrees There is continuous rise in the action potential of the infraspinatus and subscapularis to 1?0 when subscapularis shows a sudden increase to 1ɔ0 followed by a decline from 1ɔ0 to 180 The action potential of infraspinatus continues to rise to 180

Steering muscles do not act as isolated units the muscle fibres which in a particular movement steer the head vertically may act as a horizontal steerer in another movement and vice versa Thus the muscles are classified according to their role in different phases of elevation (Saha 1961)

a Innermost group of three and half steerers *viz* subscapularis supraspinatus infraspinatus and upper half of teres minor muscles supply the main power in adjusting the head The supraspinatus is the vertical subscapularis the anterior and infraspinatus and teres minor the posterior horizontal steerers in abduction

b The intermediate group of three and half muscles *viz* sternal head of pectoralis major latissimus dorsi teres major and lower half of teres minor these are mainly rollers of the humeral head but their insertions are in such a way arranged on the shaft of the humerus that their rotating action is more important Besides rotation they stabilise the head in each new position

c The last outer group of two muscles *viz*, deltoid and clavicular head of pectoralis major are primary movers insertion being far away from the fulcrum

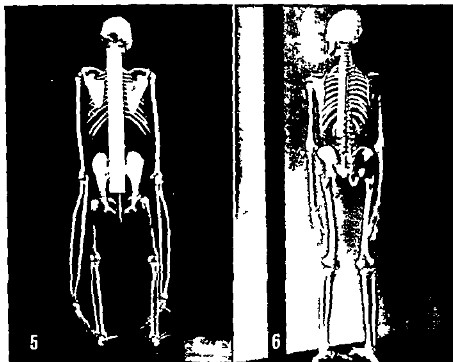
While investigating the power of the steerers that ensure the horizontal stability during movement in various directions multi lead electromyography was constantly put into use In abduction the power of the subscapularis and the infraspinatus progressively rises to stabilise the head during abduction from 60 –150 thereafter the power of subscapularis shows a rapid decline and that of infraspinatus continues to rise from 150 to 180 abduction This confirms the role of subscapularis and infraspinatus as stabilisers (Saha 1963 1964)

The subscapularis and infraspinatus stabilise from 0 –150 and infraspinatus almost alone from 150 –180 i e to the terminal phase of the abduction (Figure 4)

In brachiating primates these horizontal steerers should be more powerful than in man because of increased retrotorsion and consequently *their liability to anterior dislocation in the process of raising* the limb Subscapularis and infraspinatus fossae from which respective muscle takes its origin are relatively larger than those of human beings when compared with their height (Figures 5 & 6)

Further evidence is seen in postpolio flail shoulder where all the steerers are paralysed We treat such cases by giving vertical and horizontal steerers of the horizontal steerers preferably a posterior one is chosen In the absence of a posterior steerer we choose an anterior one from upper two digitations of serratus anterior pectoralis minor or upper part of pectoralis major whichever is available and convenient The muscles thus transferred to take over the new role of the paralysed steerers show almost similar electromyographs during abduction and flexion (Figure 7) Is the power of the new anterior horizontal steerer sufficient to stem the instability in those cases having a shallow *glenoid or enhance retrotorsion?*

In these cases we find the replacement of subscapularis by an anterior steerer is not sufficient to hold the head of the humerus



Figures 5 and 6 Back view of skeletons of gibbon and man with the same scale on the spine for comparison The scapulae in gibbon are relatively much larger than those in man confirming the necessity for origins of relatively bulkier muscles subscapularis and infraspinatus

beyond 90 of abduction The head of the humerus at this stage suddenly slips out losing its power and range (Saha 1967) These cases require a posterior horizontal steerer if available to stem the forward slipping or reduction of retrotorsion to allow the head to be retained in the glenoid cavity in absence of posterior horizontal steerer

C *Retrotorsion of the Head and Neck of the Humerus*

A quadruped has it head and neck of the humerus directed backwards and its axis is at right angle to the axis of the shaft of the humerus in the horizontal plane through the transepicondylar line and it has no torsion Torsion of the humerus starts from the primates and increases with the scale of evolution By torsion is meant the head and neck and upper shaft of humerus undergo posteromedial twist on its axis (Figure 8) This accounts for the radial groove In other words

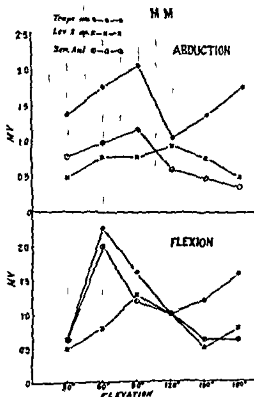


Figure 7 Electromyographs of a rehabilitated post polio flail shoulder Ordinate denotes action potential in milli volt and the abscissa elevation in degrees The upper part of the diagram shows action potential in abduction and the lower in flexion The prime mover (transferred trapezius) shows almost identical development of power in flexion and abduction The action potential of the serratus anterior (upper two digitations) shows later rise in abduction and earlier rise in flexion (horizontal steerer) The terminal notching of the curves is due to want of training and reliance upon gravity once the arm is raised above 90





Figure 8 Two stilletes one introduced in the axis of the head neck and the other through the epicondyles The right hand figure shows the retrotorsion of the humerus in bird's eye view

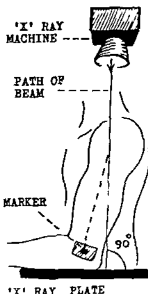


Figure 9 The Mukherjee Sivaya projection for the determination of retrotorsion of the humerus

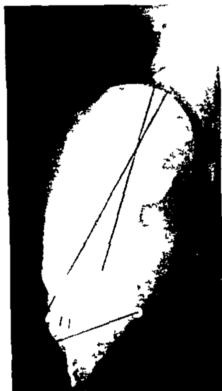


Figure 10 Retrotorsion of the humerus determined by the Mukherjee Sivaya method

the dorsal inclination of the head and neck and upper shaft found in man and christened as retrotorsion is the residual dorsal inclination of the quadrupeds Thus the primates have more retrotorsion than in men Retrotorsion may vary with races and may vary in the same individual on the two sides This is reversed in abduction and accounts for the critical stage The retrotorsion has no role in maintenance of vertical stability

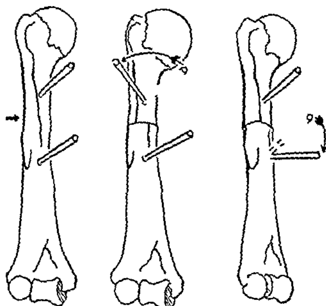


Figure 11 The two ways of reduction of retrotorsion of the humerus by osteotomy of the shaft of the humerus

Radiologically it can be determined in man by Mukherjee & Sivaswamy 10° to forward inclination of the arm depending on the bulk to reduce the soft tissue opacity around the humeral shaft in the end on view (Figure 9) Special care is taken to see that the x ray beam is at right angle to the cassette which is placed below the elbow with the required inclination The beam passes through the upper end of humerus as if this part of the humerus were in end on view Forward shift of the epicondyles does not affect the measurement of the retrotorsion angle provided the shift is made parallel to the original position of transepicondylar line in the end on view of the humerus But the junction of the neck and shaft axes being below the top of the articular surface of the humerus will be shifted a little forwards in this end on view This will introduce a small amount of unavoidable error Radio opaque markers are placed on the epicondyles before the skiagram is taken

The retrotorsion angle determined by this method was on an average of 30 amongst Indians (Figure 10)

The retrotorsion may be altered by rotation osteotomy of the upper shaft of humerus (Figure 11) (Saha et al 1967)

That arboreal primates have more retrotorsion and are liable to more instability is a paradox This naturally requires special need of power





Figures 12 and 13 Gibbon's scapula seen from above and below In both obvious retrotilt of the glenoid is seen



Figure 14 A bird's eye view of the human scapula It shows retrotilt of the glenoid

from horizontal steerers (vide supra) raising of the anterior lip of glenoid and/or enhanced transverse glenohumeral index to prevent instability Let us examine whether the glenoid possesses an enhanced anterior lip

D *Tilt of the Glenoid*

The plane of the glenoid passing through the glenoid rim is not always perpendicular to the axis of the scapula The axis of the scapula is defined as the junction of the spine with the blade The plane may be tilted in two ways—horizontal and vertical

Horizontal or anteroposterior tilt The favourable horizontal tilt which maintains the anteroposterior stability may be posterior, neutral and rarely anterior The posterior tilt or retrotilt which counteracts the horizontal instability caused by increased retrotorsion is maximum in primates when compared with that in men (Figures 12 13 and 14) Anterior tilt is found in the majority of unstable joints (Das et al 1966)

Horizontal or anteroposterior tilt in the living is determined with the help of axial radiography of the scapula in a bird s eye view position The limb is placed in 120 abduction and neutral rotation in the scapular plane A cassette preferably curved is placed over the scapula and the tube is so placed below the axilla so that the rays pass at right angle to the cassette In true axial view a long stemmed needle when passed at right angle to the posterior axillary border parallel to and in contact with the dorsal surface of the infraglenoid portion of the blade of the scapula to make its tip touch the point of attachment of the spine with the body should show in its end on view the butt tend A foreshortened needle signifies that the rays are not parallel to the infra glenoid portion of the scapula The axial view of the scapula when properly taken shows the axis of the scapula as a line superimposed on edge on view of the infraglenoid portion of the blade The glenoid appears triangular in outline depending on the tilt of the scapula in the vertical plane

The line joining its most anterior and posterior bony points (base of the triangle) gives the maximum transverse diameter of the glenoid The axis of the scapula is drawn on the skiagram by joining the mid point of this line and the junction of the base of the spine with the vertebral border Difficulties are seldom encountered in determining the axis of the scapula



Figures 15 and 16. Axial skiagrams show the retrotilt and rare anterior tilt of the glenoid.

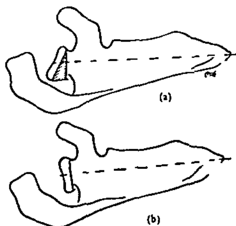


Figure 17. One of the ways of enhancing the retrotilt of the glenoid.

The tilt of the glenoid is determined from the reading on the acromial side of the axis of the scapula. 73.5 per cent had retrotilt with an average of 7.4 and 26.5 per cent had anterior tilt from 2 to 10. Similar studies were made in 21 cases of recurrent anterior dislocation (all types): anterior tilt was found in 80 per cent (17 cases) (Figures 15 and 16). The horizontal tilt may be altered as shown in the diagram by wedge osteotomy (Figure 17).

Vertical tilt. The vertical stability does not depend so much on vertical tilt of the glenoid articular surface. In the plane of the scapula the scapular axis bears an average angle of 104.9 ± 6.3 with the vertical diameter of the glenoid and is open below. The glenoid artic

ular surface normally rotates in the anteroposterior axis This makes the glenoid articular surface relatively horizontal on which the head of the humerus plays In rare instances the vertical stability may be affected by the medial inclination of the lower end of the glenoid articular surface with the axis of the scapula in other words the angle is below 90 In such rare instances the individual dislocates the glenohumeral joint downwards at will

Thus the stability of the glenohumeral joint is summarised as follows (Saha 1969)

Factors	Enhancing stability	Predisposing instability
State of development of the glenoid cavity	Glenohumeral indices 75 3 ± 7 8 and 56 6 ± 11 2 or more in vertical or transverse respectively	Glenohumeral index less than the preceding figures (hypoplasia and aplasia)
Tilt of the glenoid	A Horizontal retrotilt B Vertical *104 9 ± 6 3*	Anterior tilt Very rare for *conclusion*
Retrotorsion of the humerus	Less retrotorsion	More retrotorsion
Power of the horizontal steerers e g subscapularis infraspinatus and upper part of the teres minor	More power	Less power

SUMMARY

Dynamic stability of the glenohumeral joint is a function of developmental status of the glenoid horizontal and to a much less extent vertical tilt of the glenoid retrotorsion of the humerus and the power of the steerers particularly the horizontal steerers (in abduction) The horizontal steerers include subscapularis infraspinatus and upper half of the *teres minor*

Morphological studies determination of the tilt of the glenoid and

retrotorsion of the humerus were done anthropometrically and radiologically both in the normal and in cases of recurrent anterior dislocation of the shoulder

Simultaneous electromyography of the muscles of shoulder during abduction and flexion were extensively used in the normal and in the rehabilitated flail shoulder following poliomyelitis and brachial plexus injury

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Dept of Orthopaedic Surgery Aalborg Sygehus Syd 9000 Aalborg

FRACTURES OF THE HUMERUS FROM MUSCULAR VIOLENCE

Hans N Gregersen

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According to the literature fractures of the shafts of long bones due to muscular violence alone are uncommon There are reports from the United States Finland and Germany of fractures of the shaft of the humerus sustained while throwing the javelin the baseball or hand grenades (Bingham 1959 Clemmons & Hammond 1947 Heiss 1960 Herzmark & Klune 1952 Krainz 1939 Peltokallio 1968)

The aetiology of these fractures has been in doubt Most authors attribute them to violent uncoordinated muscular action on the bone but some believe that they are just due to stress (Boje 1942 Petersen 1970)

The following four cases are described as further examples of fractures caused by throwing

CASE HISTORIES

1 The first patient was a well trained soldier of 24 years of good previous health and of medium height and weight The incident occurred when he was trying to throw a hand grenade as far as possible He suddenly experienced a painful crack in the right upper arm which then fell limply to his side On arrival at hospital he was found to have a simple fracture of the lower third of the right humerus without vascular or neural lesion Radiography showed this to be a spiral fracture with a large butterfly fragment at the junction between the middle and distal third of the humerus (Figure 1) The arm was treated in a hanging cast for seven weeks after which the fracture was found to be united clinically and radiologically in a satisfactory position Three weeks later there was full movement in the upper limb with no sign of nerve injury



2 The second case too was a ... previous health While throwing a ... suddenly got a spiral fracture of ... radiologically the fracture was ... patient There was no sign of ... was treated in a hanging cast for six ... radiologically found to be united ... he had full movement in the upper ...

3 The third case too was a sold... For several years he had played ... the ball violently he got a spiral fr... ment in his right humerus The ... were similar to the two previous ... a hanging cast the fracture was ... There was considerable limitation ... at the elbow but no sign of nerve ... ment had returned to the arm

4 The fourth patient was a 17... health She had been an active ... years During a violent throw in a ... the right elbow and the upper arm ...

Figure 2 Fracture initially The fracture has been set off with ink



our accident department because of persistent pain in the upper arm Examination showed there to be some swelling and tenderness just above the elbow but no other sign of fracture or of neural injury Radiography showed a fine but distinct fracture line at the junction of the middle and lower third of the humerus (Figure 2) The arm was treated in a simple sling Eleven days after the accident she complained of slight paraesthesia on the dorsum of the fingers of the right hand The site of the fracture was still sore and radiography showed the fracture to be unchanged Four weeks later the fracture was found to be healed and there was full movement in the upper limb with no sign of nerve injury

DISCUSSION

Injuries to the elbow joint in people who are throwing objects are well known and have been fully described by Waris (1946) These are usually detached fractures from the olecranon or fragments from the articular surfaces and are quite frequent in javelin throwers

Fractures in the humerus have been described in javelin throwers baseball players and hand grenade throwers but fractures occur much less often than joint injuries Typically these fractures occur at the junction of the middle and lower thirds of the shaft of the humerus



Figures 3 a b c The overhand throw Three stages

at the level of the radial groove the fractures are spiral often with a butterfly fragment of large or small size

It is thought that the manner of throwing is the chief factor in causing these fractures In over arm throwing (Figures 3 a b, c) the arm executes a violent forward and upward movement from the externally rotated position in adduction with extended elbow and shoulder Soon after the action begins the elbow is flexed to a maximum of 90 degrees when half the throw has been carried out At the end of the throw when the arm has passed the vertical position the elbow is suddenly extended and there is at the same time a sudden internal rotation of the arm immediately after which the missile is released To achieve a correct throw there is a simultaneous movement of the trunk and lower limbs with the feet being correctly positioned and the body twisting A torsional strain is exerted on the shaft of the humerus during the course of the throw and the amount of this depends on the weight of the missile (javelin 800 grams baseball about 200 grams hand grenade about 700 grams)

The muscles which externally rotate and lift the arm from the extended position are chiefly the deltoid the supraspinatus and the infraspinatus and teres minor Internal rotation at the end of the throw is chiefly due to the pectoralis major the subscapularis the pronator teres and brachioradialis The flexion of the elbow is produced by the biceps and brachialis while the extension is effected by the triceps The whole throw is thus very complex and a successful throw requires well co-ordinated actions of all the muscles involved

At the point of throw when external rotation is transferred to internal rotation and when flexion of the elbow changes to extension the torsional force acting on the humerus is at its maximum and it is at this point that fracture occurs If during the throw the actions of the muscles involved become uncoordinated so that external rotation is not completed before internal rotation starts the chance of fracture increases Finally an incorrect throwing technique in which the upper arm is too violently abducted with inadequate flexion at the elbow may predispose to fracture

Case 4 is an example of a fatigue fracture which resulted from frequently repeated minor traumata without the arm being heavily loaded at any time We have discussed and tried to investigate whether the x ray shadow is only due to nutrient vessel but we doubt that this is the case The other three cases can be considered to lie in the border line between fatigue fractures and those due to greater torsional

strains As the fractures occurred when the force exerted was at its maximum it may be argued that large stresses were involved but fatigue fractures are perhaps more likely as these three throwers had undertaken the same movements so many times before though the force used on each occasion was greater than the throwers were accustomed to employ

Kramz (1939) stated that fractures resulting from throwing tended to heal slowly We have not found this to be so in our series

It is remarkable that radial nerve injuries have only once been reported in patients sustaining this type of fracture (Shang Liang Chao et al 1971) The fractures are almost always situated at the level of the radial groove and the fragments may be badly displaced Our fourth case had some paraesthesia on the dorsal surface of the radial fingers but no motor paresis The symptoms can be explained by hematoma developing round the radial nerve

The radiographs did not show any pathology in the bones apart from the fractures Healing times were normal and no patient showed any sign of abnormally brittle bone structure

SUMMARY

A series of cases is presented in which similar fractures of the shaft of the humerus have occurred in four patients all of whom were throwing over arm Two of these were throwing hand grenades and two were playing handball The mechanism of the fracture is discussed in detail and it is concluded that they are stress fractures due to torsional violence

One patient developed a transient radial nerve lesion probably due to hematoma in the radial groove No patient seemed to have any pathological brittleness of the bones and all united in normal time

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University Children s Hospital Helsinki Finland

EARLY OPERATIVE TREATMENT OF CONGENITAL CLUB FOOT

E Somppi & M Sulamaa

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Club foot talipes equinovarus is a common congenital malformation Opinions concerning the optimal primary treatment are however still divergent Hersh (1967) reported that 50 per cent of the deformities were not corrected by conservative treatment and in Tonnis s and Bikadorov s series of conservatively treated cases the result was poor in 58 per cent The material of our hospital presented by Solonen & Parkkulainen (1957) showed that 38 per cent were treated by conservative means and 62 per cent operatively The over all results were unsatisfactory in 19 per cent The cause of failures was considered to be the inability to achieve sufficient correction by manipulation in severe cases Therefore since 1958 we have adopted early operation for cases of severe and moderate degree of malposition A preliminary report of the results was given by Pasila & Sulamaa (1961)

As a rule conservative treatment is recommened by most authors at an early age Late results of early operative treatment have not been published This paper reports a follow up examination of 54 patients operated on for club feet under 2 weeks of age during the period 1959–1966 There were 33 bilateral cases which means that the number of operated feet was 87

PRINCIPLES OF TREATMENT

A modification *of Brockman s operation a medial release combined* with achillotenotomy has been used In a bloodless field an incision is started behind the medial malleolus and extended downwards over the region of the navicular bone The tendon of the posterior tibial muscle is severed and its distal end removed The navicular bone is widely freed from its dorsal proximal and plantar attachments the talo-navicular joint thus becoming widely opened The deltoid liga

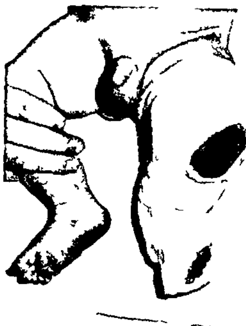


Figure 1 Typical postoperative plaster cast for immobilisation in overcorrected position

ments are excised thoroughly and often even the talo calcaneal joint is opened medially The Achilles tendon is severed through the same incision A sufficient correction is now easily seen from the relation ship of navicular and talus bones After securing hemostasis the wound is closed with catgut sutures The overcorrected position is maintained with a flannel bandage supported by a plaster cast for about 4 months Later Denis Browne splints are used until walking age Night splints and talipes boots are used up to the age of 3–4 years (Figure 1)

MATERIAL

During the period 1959–1966 168 patients were operated on for club foot deformity and 97 were treated by conservative means only In 73 patients or about one fourth of the cases the operative treatment started under 2 weeks of age Fifty four were traced and thus a follow up was made of a total of 87 feet 33 cases having a bilateral malformation In 19 cases the status has been considered satisfactory at the end of the treatment but the patients could not be traced at the time of follow up due to changes of the home addresses The ratio of boys to girls was 69 per cent Re evaluation of the operation accounts revealed that release of the intertarsal ligaments in 18 feet had been insufficient or not radical enough thus only 69 feet had been treated in the way which at present is considered adequate The wound healing and the postoperative treatment were evaluated on the basis of the infection complications the duration of plaster and splint im

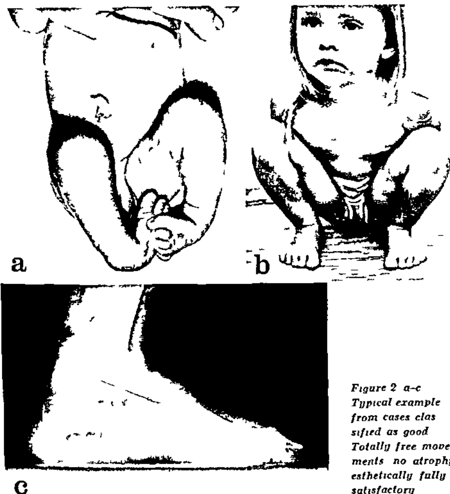


Figure 2 a–c Typical example from cases clas sified as good Totally free move ments no atrophy esthetically fully satisfactory

mobilisation as well as the duration of the use of night splints and special boots Twelve club feet of infants suffering from arthrogryposis multiplex or myelomen ingocele teratologia cases were separatel grouped as well as 8 feet having sup purative wound infections These infections caused no other complications but made the immobilisation during postoperative treatment less effective Other complications of the operation were not seen

The follow up examination recorded the details of growth muscular atrophy limitations of mobility and the residual deformities as well as the cosmetic appearance and the functional result From x ray pictures the shape of the tarsal bones and their position in relation to one another were evaluated The results were classified as good fair and poor Photographic demonstrations and x ray pictures of cases belonging to these classification groups are presented in Figures 2–4

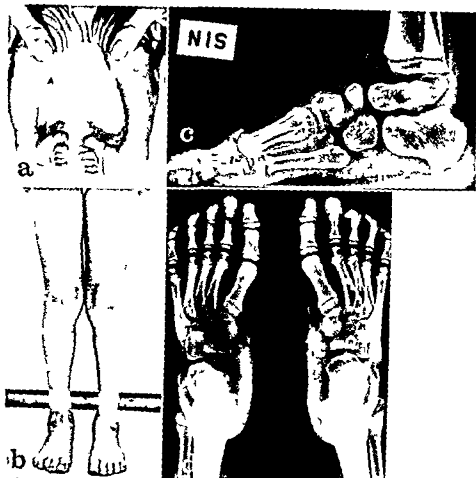


Figure 3 a–d A case classified as fair Satisfactory movements muscular atrophy in the calves slight planovalgus on both sides cosmetic result not totally satisfactory Radiologically horizontal talus and metatarsovarus are seen

RESULTS

From Table 1 it can be seen that in about half of the cases combined with arthrogryposis or meningomyelocele the result of operative treatment was poor and a good result is uncommon Good results after postoperative infection were likewise rare However even after uncomplicated healing the result was poor in about 20 per cent A clear correlation to the results could not be found concerning the extent of the ligament release in the primary operation or the duration of the postoperative plaster treatment and the use of night splints and special boots

Table 1 Results at follow up

	Number of feet			
	good	fair	poor	total
Club feet associated with arthrogryposis myelocele etc	1	5	6	12
"Simple" club feet	29	31	15	75
Wound infection	(2)	(4)	(2)	(8)
Total	30	36	21	87

The following counts of residual deformities were registered

- visible metatarsovarus in 24 feet
- equinus in 13 feet
- slightly impaired extension of the ankle in 37 feet
- some varus or valgus ankle in 55 feet

The unilateral cases presented slight length difference in 7 cases muscular atrophy of the calf in 16 cases the same of the thigh in 8 cases and bony atrophy of the affected forefoot in 18 cases

The x ray pictures taken at the follow up presented atrophic changes of the navicular bone in two-thirds of the operated feet In lateral projection the talus was more or less deformed and in horizontal position in nearly half of the operated feet Metatarsovarus deformity seen also clinically was found more or less severe in one third of the operated feet The talo-calcaneal angle was measured At follow up the mean in normal feet of the unilateral cases was 25 and 15 on the operated side Only about one third of the operated feet presented an angle of more than 20 There seems to be a positive correlation between the clinically good result and talo-calcaneal angle of more than 20

DISCUSSION

An evaluation of the results of treatment of club foot deformity is difficult In practice cosmetic appearance and the functional capacity at follow up after at least 3 years seem to be the most important criteria The significance of radiologically verified tarsal bone deformities is obscure because too little is known about their late osteoarthrotic sequels Figure 5 presents x ray of a club foot with a hor

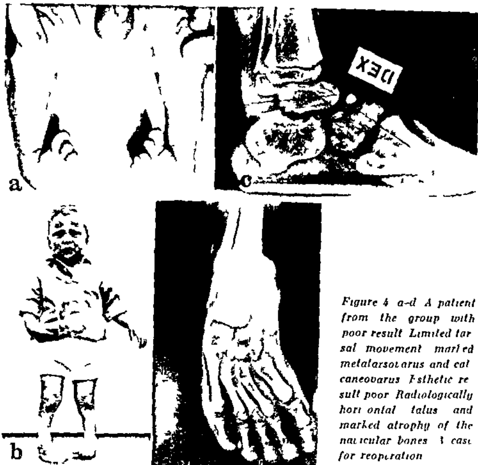


Figure 4 a–d A patient from the group with poor result Limited tarsal movement marked metatarsovarus and calcaneovarus Esthetic result poor Radiologically horizontal talus and marked atrophy of the navicular bones A case for reoperation

deformed talus The cosmetic result is poor but the function has been rather satisfactory There is neither pain nor arthrosis deformans It is also pointless to compare the results in different materials consisting of patients treated at different age groups by several therapeutic methods Conservative treatment alone leads to a satisfactory result in only 50 per cent of the cases according to Hersh (1967) and in 60 per cent in Weseley & Barenfeld's series (1968) As the soft tissue operations according to Tonnis & Bikadorov (1968) gave satisfactory results in only 70 per cent 15 per cent poor results of all cases still remain Reimann's series of 108 operated feet showed 10 per cent poor results The 19 per cent unsatisfactory results in our first series is in accordance with these statements Since 1958 our aim has been to adopt conservative treatment in mild cases only and operate early all cases with uncertain outlook The 24 per cent poor

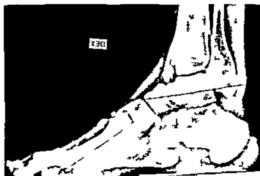


Figure 5 X ray of a club foot treated conservatively 60 years ago

results in our series of early operated cases of selected severity cannot be estimated unfavourably because the share of poor results remains less than 10 per cent of all cases treated

Failures in the operative release or in the postoperative treatment were considered to be reason for poor results but no significant correlation could be found A horizontal talus and a talo-calcaneal angle of less than 15 were observed at follow up in x rays of poor cases In infants the measurement cannot however be done exactly and thus an x ray control has not full value during the most important time of therapy

Scheel (1958) emphasizes the decisive importance of very early but nontraumatic manipulative treatment and most authors postpone operative intervention to over 4 months age Hersh (1967) however favours achillotenotomy during the first weeks of life and soft tissue release after 3 months Hirsch (1960) has performed soft tissue release at 2 months of age and Wesley & Barenfeld (1968) the same after 5 months of age Jacquemain (1968) operating at 4 to 6 months had poor results in 15 per cent only but Herwig (1958) verified deformity of the talus in 28 per cent of the navicular in 35 per cent and of the calcaneus in 17 per cent of the cases operated by this (Scheel s) method In Reimann s series (1967) most poor results were found in cases where only posterior but not medial release was performed The demand of early but forceless manipulation cannot be accomplished in rigid club feet An attempt to prevent further shrinkage of the ligaments and malgrowth of the tarsal bones by early operative release was made in our series with success in 76 per cent but 24 per cent of feet are poor or in need of reoperation Our experience has shown the possibility of operation at an age of less than 2 weeks with good results In our opinion there is no reason to postpone an operation for

more one month if the prognosis of treatment by conservative means is uncertain

SUMMARY

A five year follow up study of 87 primarily moderate or severe club feet operated on under 2 weeks of age by medial release and achil lotenotomy is presented Good or fair results were found in 76 per cent and poor results in 24 per cent The possible advantages of early operation in severe cases are discussed

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Department of Orthopaedics and Traumatology
University Central Hospital Helsinki Finland

CHONDROMALACIA OF THE PATELLA

A Follow Up Study of 25 Cases Treated with Chondrectomy

E WILPPULA & V VAHVANEN

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Degeneration of the patellar cartilage is a phenomenon described long ago (Budinger 1906) and many studies on chondromalacia of the patella (ChP) have been published (Øwre 1936 Hinricsson 1939 Wiberg 1941 Friberg 1941 Hirsch 1944) Nonetheless many etiological and therapeutic problems remain to be solved The purpose of this study was to discuss these problems on the basis of a clinical series

MATERIAL

The series consists of all ChP cases operatively treated at the Department of Orthopaedics and Traumatology University Central Hospital Helsinki during the years 1952–1969 Follow up examinations were carried out in 1970 The series comprises 35 patients treated by shaving of the degenerated patellar cartilage Patellectomy was not performed in any case. In addition the degenerated cartilage of the medial or lateral femoral condyle was removed in 7 and 4 patients respectively and the medial or lateral meniscus was removed in 9 and 3 patients respectively including a cyst in the lateral meniscus A loose intra articular fragment was removed in 9 cases and partial synovectomy was performed in 2 cases Sequalae of a healed fracture of the distal portion of the patella was observed in one case Shaving of the cartilage of the under surface of the patella without any other procedures was performed in 10 patients only Of the patients 20 were male and 15 female At the institution of treatment the youngest patient was 14 and the oldest 55 years old the mean age being about 33 years The right knees numbered 18 the left 17

Etiology

There had been no trauma in 14 cases whereas 21 patients gave a history of some kind of injury to the knee joint Twisting was the commonest trauma mechanism (18 cases) One patient had fallen from a height and one had received a direct blow to the knee joint A fragment of a shell was found in the extensor muscles of the knee

joint in one patient it had been there since the war or for about 19 years A predisposition to luxation of the patella was observed in 2 patients One of these could not remember any trauma in the past

Preoperative Clinical Features

The duration of clinical symptoms from the onset to the times of operation ranged from 2 months to 13 years the mean being 3 years The initial treatment was conservative in all cases If this proved unsuccessful the knee joints were operatively treated Three patients experienced slight pain in the knee joint on walking for longer distances especially on rough ground and stairs The pain on walking was moderate in 25 cases and severe in 7 Compression of the patella against the femur was painful in 19 patients but the symptom was negative or uncertain in 11 and data were lacking in 5 Painful compression of the patella was invariably associated with crepitation Painless crepitus was observed in 11 patients Nineteen patients had experienced momentary locking of the knee joint which had easily been relaxed Effusion in the knee joint was observed in 18 patients Instability of the tibio femoral joint was not present in any cases A predisposition to luxation of the patella was present in 2 cases Movement of the knee joint was in general normal and the same as on the other side Three patients showed slight limitation of flexion (by 10–20 degrees), and three showed increased limitation of flexion (by 40 degrees at most)

Preoperative Radiological Findings

The X ray findings in the knee joint were normal in 15 patients Unevenness of the under surface of the patella was observed in 3 cases including one showing a healed fracture of the patella A loose intra articular fragment was found in one case Slight osteoarthrotic changes such as slight osteophytes sharp tibial eminences or slight narrowing of the joint spaces or osteosclerosis were observed in 3 patients Data were lacking in 11 cases In 2 cases arthrography raised a suspicion of meniscal rupture Tomography was not performed in any of the present cases

RESULTS

All patients were followed up until the end of treatment In addition all patients were summoned to a follow up examination 3 14 years

after operation the average interval being 6 2 years End results were obtained in 25 out of the 35 cases Postoperative complications were observed in 2 patients i e slight wound infection in one and deep thrombophlebitis of the leg in the other

Pain was not present in 9 patients Nine patients experienced slight pain on walking for longer distances (several kilometres) and on stairs or on squatting Six patients experienced moderate pain and one patient experienced severe pain

Walking was completely normal at follow up examination in 19 patients whereas 6 patients walked with a marked limp Three of these used a cane

Squatting succeeded completely in 14 patients to about half way in 8 patients and less than half way in 3 patients

Effusion in the knee joint was observed in 5 patients no effusion in 20 patients

Crepitation of the patella was present in 19 cases and absent in 6 Crepitation was associated with moderate pain in 4 cases and slight pain in 6 whereas 15 patients experienced no pain when the patella was pressed against the femoral condyle

Locking had occurred in four patients

Instability of the tibio femoral joint in slight flexion of the knee was observed in 2 cases and in full extension in one case The backward drawer symptom was noted in one instance Luxation of the patella could be provoked in 2 cases

Movement of the knee joint was limited in 6 patients The limitation was moderate in 3 patients flexion being between 100 and 90 degrees

The *radiological finding* was normal in 10 cases Slight arthrosis and unevenness of the under surface of the patella was observed in 10 cases In one of these a small loose fragment was observed in the central posterior portion of the joint Moderate or severe arthrosis was observed in 5 cases and the changes clearly increased during the time of observation Four of these patients were over 50 years old at follow up In spite of arthrosis the functional result was good in one patient fair in two and poor in one

The *subjective end result* was good in 11 patients better than the state before operation in 8 patients about the same or worse than before operation in 6 patients These 6 experienced pain in the knee One of them showed sequelae to a fracture of the patella

Functional end result The results were classified as good fair or poor according to the follow up results and the subjective opinion of

the patient. The result was considered good if the function of the knee joint was fully normal and painless and crepitus of the patella was painless. The result was considered fair if exertion of the knee caused pain which was slight although it was a source of discomfort during the patient's professional or other daily work and if the state was better than before operation. The result was considered poor if the patient regarded the treatment as unsuccessful and this was corroborated by clinical examination. One case of re-operation is included among the poor cases. The results were good in 13 cases, fair in 8 and poor in 4. Ten patients were omitted from evaluation.

The *poor end result* was attributed to severe arthrosis in two patients who experienced moderate or severe pain in the knee joint. Of these patients one showed luxation of the patella, a tendency towards luxation having been observed even before operation. In the other patient a ruptured meniscus and a fragment from the femoral condyle were removed at the operation. This patient was 55 years old. In a third case pain was present on exertion and on squatting. There was effusion in the joint and compression of the patella caused painful crepitus. Motion of the joint was good and no arthrosis was observed at follow-up. Chondromalacia of the patella was the only diagnosis. Re-operation was carried out in one case because the knee joint was painful after the primary operation. At the second operation both menisces were found to be injured and were therefore removed. After this operation the knee joint has been symptomless. The results in the traumatic cases (16 patients) were classified as good in 10 cases, fair in 3 and poor in 3 cases. The results in the remaining 9 patients were good in 3 cases, fair in 5 and poor in one case.

Fourteen patients were able to continue in their previous professions. Five patients without a profession performed domestic work. Two patients had to change their professions and chose lighter work because of their knee symptoms. Four patients were retired at the time of follow-up.

DISCUSSION

The mean age of the patients in the present series was 33 years. According to Øwren's (1936) findings in an autopsy series chondromalacia (ChP) is most frequent in the age groups 20–35 years. Wiberg (1941) observed roentgenological changes due to ChP in nearly every 30 year old patient. In our series roentgenological changes due to ChP were detected before operation in only three of 24 patients.

The role of trauma in the etiology of ChP is not beyond dispute but many authors have considered it as important (e g Crock 1964 Bentley 1970) In an experimental study Hirsch (1944) reported that degeneration of the patellar cartilage was induced by trauma In our series 21 of 35 patients gave a history of trauma to the knee joint In 18 of these 21 cases the injury was due to twisting of the knee joint without any blow to the patella It may be assumed that the motion of the patella had been suddenly and severely disturbed and that this had caused a locally increased mechanical stress on the patellar cartilage According to many authors exceptional mechanical stress on the patellar cartilage may be due to an unusual shape of this cartilage or of the femoral condyle (Wiberg 1941 Outerbridge 1961 1964 Crooks 1967) or to rotatory instability of the knee joint (Hughston 1969) From the frequent occurrence of other lesions such as meniscal rupture luxation of the patella and a loose body which in our series were found in 25 of the 35 patients the conclusion may be drawn that the deficient function of the joint associated with these lesions increased the progress of ChP It is possible that in those patients who had a history of trauma ChP was already present in a latent phase and the trauma then led to aggravation of the disease and its symptoms Certain studies seem to indicate that mild symptoms of ChP are quite common (Silverskiold 1938 Wiberg 1941) The absence of known trauma in the etiology of 14 of the present 35 patients is more difficult to understand The anatomy of the femorpatellar joint was not specifically examined It is possible that anomalies in the anatomy or function of the femorpatellar joint were present in the cases in question These possible etiological factors have previously attracted attention (e g Wiberg 1941 Outerbridge 1961 1964 Crooks 1967 Hughston 1969) According to Rubacky (1963) chondromalacia of the patella may sometimes be hereditary

The frequent occurrence of other lesions in the knee joint showing ChP (in 25 of 35 patients) shows that this possibility must be borne in mind when planning the treatment of ChP In our opinion operative exploration of the joint must therefore be extensive Preoperative arthrography is important because of the frequency of meniscal ruptures (12/35) Owing to the composition of the present series we can hold no opinion concerning the value of conservative treatment of ChP Many authors have stated that mild cases of ChP may be conservatively treated (Karlsson 1940 Cahen 1957 Devas 1961)

In our series ChP was treated only by shaving of the patellar carti

lage No patellectomy was made The results may be considered as relatively satisfactory since only 4 of 25 patients had poor results Of these only one was a bare ChP case the remaining three showed other lesions of the knee joint as well which influenced the prognosis In spite of deterioration of arthrosis during the observation time the condition of the knee was better than before operation This seems to indicate that it is important to treat the symptoms of ChP even though arthrosis which may be symptomless may be present in other parts of the knee Shaving of the degenerated patellar cartilage is the operative method which we recommend Many authors have done the same (Karlsson 1940 Wiles et al 1956 1960 Langenskiold 1971) although others have found shaving of the cartilage unreliable (Bentley 1970) Some writers prefer patellectomy as an operative method either invariably (Cahen 1957) or at least in severe cases of ChP (Friberg 1941 Outerbridge 1961 1964 Crooks 1967) At the time of follow up no case in the present series had required patellectomy

CONCLUSION

Indirect injury of the knee joint seems to be an important factor in the etiology of chondromalacia of the patella (ChP) ChP is often associated with other lesions of the knee joint and this possibility must be borne in mind when planning the diagnosis and treatment Shaving of the degenerated patellar cartilage was done with good results

SUMMARY

A series of 35 patients showing chondromalacia of the patella (ChP) is presented Twenty five patients were followed up A history of injury to the knee joint was elicited in 21/35 patients Shaving of the degenerated patellar cartilage was done with good results The result was poor in 4/25 cases Other concurrent lesions of the knee joint such as meniscal rupture loose body and luxation of the patella were common (25/35 patients) This possibility must be borne in mind in the diagnosis and treatment of ChP The presence of other lesions is likely to influence the prognosis

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1 Control group in which the footplate and thereby the calcaneus was in a 30 angle in relation to the long axis of the tendon in the frontal plane The elongation was performed quickly with simultaneous stimulation of the muscle The initial length was the length of the muscle tendon group at 90 flexion in the ankle and approx 40 flexion in the knee

2 Slow traction the elongation of the muscle tendon group being performed appreciably more slowly than in the control group

3 Straight traction with the footplate and thereby the calcaneus in a neutral position instead of 30 angulation

4 No stimulation when the loading experiment was done without stimulation of the muscle

5 Exhausted when the muscle during a period of 3–5 min was exposed to tetanic stimulation until exhausted so that the contraction force fell to 5 per cent of the maximum isometric force Thereafter the stimulation was interrupted and the next moment the loading experiment was performed

6 Short initial length means that the initial length corresponded to the shortest possible length of the muscle tendon group in the intact leg + 25 per cent of the greatest possible excursion

All the parameters were entered on paper tapes and the material was analysed in a GIER computer

Unless otherwise stated the linear regression equations were determined for the parameters and compared between the groups

The groups were compared with the control group but as the body weight and sex ratio were extremely varied (Table 1) and as many of the relations were found to change with increasing weight especially in the case of the largest rats (Barfred 1971 c) the control group was divided into a large and a small sub group which as already mentioned showed the same distribution of ruptures To exemplify the dependence of the parameters upon weight the separation force muscle force relations are shown in Figure 1 for the small and the large control sub group

In stating the results below the comparison against the entire control group has been checked by comparing with the large control sub group and if indicated by comparing males or females from the variation group with the corresponding sex in the control group

A significant difference from the control group was rejected if the fractionated comparison was insignificant unless there was still a distinct tendency to the named difference

Comparison between the right and left leg and comparison between the leg first exposed to experiment and the second leg were done by applying the t test to the difference

For comparing the distribution of the site of rupture in the various groups the approximate χ test was used

Differences were considered significant when $p < 5$ per cent

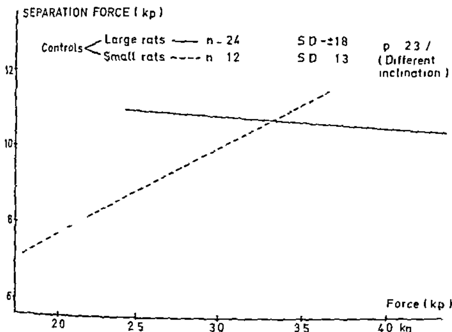


Figure 1 Correlation between separation force and muscle force in recently captured large wild rats The broken line represents the regression equation for the 18 smallest rats the solid line the regression equation for the 24 largest rats The difference between the inclination of the lines is significant Force unit $Kp = 9.81 \times 10^5$ g cm/sec^2 = 9.81 N (Newton)

RESULTS

The distribution of the site of rupture in the various groups is divided in Figure 2 into 4 types fixation ruptures tendon ruptures muscle ruptures and other ruptures The latter signifies ruptures at tendon insertion or muscle origin with avulsion of a bone fragment from the calcaneus or condyles and also includes ruptures at the muscle tendon junction

The number of experiments on right and left legs was approximately the same in all groups The right leg experiments corresponded to pronation and the left leg ones to supination of the foot No significant difference was found between right and left legs from rats on which the same procedure was used on both sides

The duration of anaesthesia might also have influenced the experimental results *inter alia* because some of the rats went into shock However a comparison between the first and second leg on rats having the same type of experiment on both sides showed no signifi

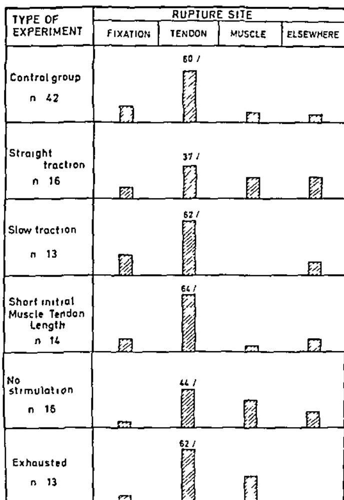


Figure 2 Dependence of distribution of rupture site upon type of experiment on recently captured large wild rats The height of the columns is determined by the percentage number of ruptures

On comparison with the tendon ruptures in the control group p = 13 per cent

cant difference The duration of the anaesthesia had been approx half an hour longer for the second than for the first leg

Straight traction The only change in procedure in this group as compared with the control group was that the calcaneus was in a neutral position The incidence of tendon rupture (Figure 2) dropped to 37 per cent (p = 13 per cent) At the same time the number of muscle ruptures increased from 5 out of 42 (12 per cent) to 4 out of 16 (25 per cent) Although the values are not finally convincing the

straight traction appears to have distributed the risk of rupture to all parts of the bone muscle tendon bone group whereas the oblique traction appears to concentrate the risk on the tendon

The elongation muscle tendon length relations as well as the separation force-muscle force relations differed significantly on comparison between the straight traction and the control group Both relations showed that the regression line was steepest for straight tractions so that elongation and separation force were less than in the control for the smallest rats whereas no major difference was found between the large ones Otherwise there were no differences between the groups

Slow traction The incidence of tendon rupture and the distribution of the ruptures were the same as in the control group The change made in this group was that the speed of traction was slower an average of 94 per cent/sec as compared with the control group in which the elongation averaged 257 per cent/sec (stated as per cent of muscle tendon length)

On comparison of the various parameters no difference from the control group was detected

Short initial length In the control group the initial length was the length of the muscle tendon group when the foot was in 90 flexion and the knee in about 30 flexion This length was about 2 mm shorter than the greatest possible length of the muscle tendon group (called muscle tendon length) As a short initial length the author chose the shortest length that the muscle tendon group could have (maximum flexion in the knee joint and plantar flexion of the ankle) + 25 per cent of the excursion The excursion was almost 10 mm the length of the muscle tendon group about 50 mm

This procedure did not alter the distribution of the type of rupture (Figure 2) The separation force in relation to muscle force and body weight as well as $\Delta L_{1\ 5}$ in relation to muscle tendon length was the same in both groups In relation to muscle tendon length both L_0 and elongation were significantly greater in short In absolute figures the average elongation in the control group was 13 2 mm and in the short group 16 mm The difference in the initial length was 4 9 mm Thus the final length (initial length + elongation) of the muscle tendon group obtained at rupture was 1 9 mm less in the "short than in the control group The final length muscle tendon length relation showed this difference to be significant

In this connection it must be mentioned that the final length was never less than the muscle tendon length As mentioned in the previ-

ous paper the lower leg was cut except for the Achilles tendon before the rupture experiment In one rat of those which had been kept in a run (Barfred 1971 c) the elongation at tendon rupture was only 3 3 mm corresponding to a final length of 1 3 mm more than the muscle tendon length If this experiment had been performed with a short initial length the final length might have been presumed to be 1 9 mm shorter and thus the tendon rupture could have taken place without exceeding the muscle tendon length In this case the heel region was oedematous but the tendon itself was normal grossly as well as microscopically

In 6 legs the final length corrected as above was less than 3 5 mm greater than the muscle tendon length Of these 6 legs 3 were from the control group 2 from the straight traction group and one from the group kept in a cage for 3 months after being captured (Barfred 1971 c) These tendons showed no gross or microscopic changes in

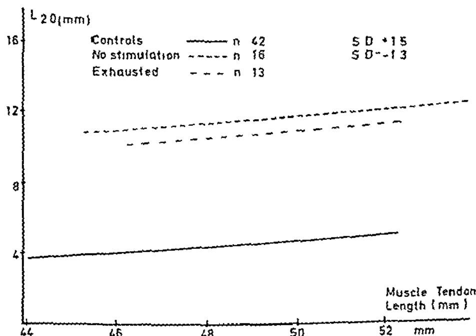


Figure 3 Correlation between L_{20} and muscle tendon length L_{20} is the elongation at the tension which corresponds to 2 × the maximum isometric force The lines represent the regression equations for the control group the no stimulation group and the exhausted group The difference between the control and the exhausted group is significant ($p \approx 0\,0$ per cent) whereas that between the exhausted group and the no stimulation group is not significant ($p \approx 8\,4$ per cent)

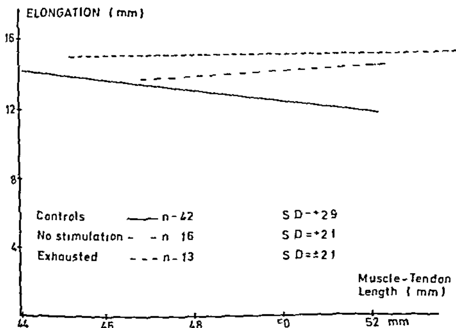


Figure 4 Correlation between elongation at rupture and muscle tendon length for the control group no stimulation group and exhausted group The lines represent the respective regression equations The difference between the control group and the no stimulation group is significant (p= 1 1 per cent) Otherwise no significant difference between the groups

explanation of the short elongation at rupture The 7 legs just mentioned were from 4 groups totalling 84 experiments

No stimulation In this group the incidence of tendon rupture fell from 25 out of 42 (60 per cent) to 7 out of 16 (44 per cent) The difference was not significant There seems to be a tendency to a larger number of muscle ruptures in this group

The elongation muscle tendon length as well as L_{20} muscle tendon length relations disclosed that elongation and L_{20} were significantly greater than in the control group (Figures 3 and 4)

The separation force was significantly less in relation to force and to log weight

ΔL_{15} was significantly less in the control group corresponding to a greater inclination in this part of the length tension diagram

Exhausted The incidence of tendon rupture was exactly like that in the control group At the same time there seemed to be a ten

to a larger number of muscle ruptures just as in the no stimulation group

Figures 3 and 4 show that the elongation and L_{20} in relation to muscle tendon length were greater than in the control group but the difference was significant only for the L_{20} muscle tendon length relation

Just as in the no stimulation group ΔL_{15} was significantly lower in the exhausted group than in the control group

Neither the separation force muscle force nor separation force log weight relations were different from those in the control group

Comparison between no stimulation and exhausted did not show any significant difference between any of the named relations but the values for exhausted were always between those for control and no stimulation

The elongation muscle tendon length relation (Figure 4) exhibited a difference which might indicate that an exhausted muscle was stiffer than a non stimulated one but $p = 14$ per cent

As already mentioned the rupture experiments in both these groups were performed without stimulation but those in the exhausted group had been immediately preceded by 3–5 min tetanic stimulation which exhausted the muscle so much that its force was less than 5 per cent of the maximum isometric force

Comparison Within the Groups

The site of rupture in the bone muscle tendon bone chain is determined to some extent by the animal s conditions of living and by the experimental procedure Furthermore it could be expected that properties in the individual animal might influence the site of the rupture

A comparison of muscle and tendon ruptures within the control group showed that the muscle force appears to have a major influence upon the type of rupture (Figure 5) The comparison was performed as muscle force log weight and muscle force muscle tendon length relation with the same result The 5 muscle ruptures occurred among the rats which were rather small (250–345 g) had a fairly short muscle tendon length and significantly less muscle force than the entire control group From the same figure it is apparent that these criteria were not tantamount to the result of the rupture experiment being a muscle rupture

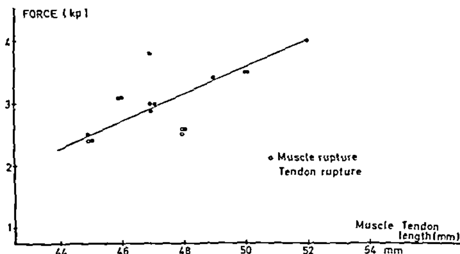


Figure 5 Correlation between force and mus le tendon length The line represents the common regression equation for muscle and tendon ruptures in the control group Muscle rupture (n = 5) and tendon rupture (n = 25) are marked differently SD ± 0 1 and ± 0 4 respectively The difference between muscle rupture and tendon rupture is significant (p = 1 1 per cent)

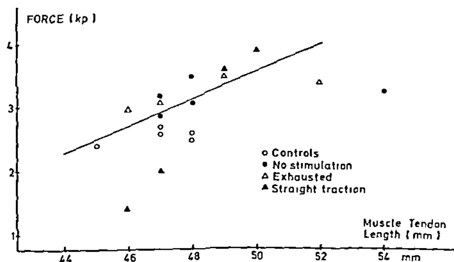


Figure 6 Correlation between force and muscle tendon length for muscle rupture in the control group no stimulation group exhausted group and straight tra t group The l ne represents the common regression equation for muscle and t ruptures in the control group

The slow group was not represented in the danger zone with respect to muscle rupture and indeed no muscle ruptures occurred The group short initial length was represented by one leg in this zone The result was muscle rupture the only one occurring in the group

In three groups no stimulation exhausted and straight traction 5 4 and 4 muscle ruptures occurred (Figure 6) All the muscle ruptures in the exhausted and in the no stimulation group occurred in large rats with a fairly great muscle tendon length and significantly greater muscle force than those showing muscle ruptures in the control group These two groups are not represented by more than one leg each in the zone in which the muscle ruptures of the control group occurred In both cases the result was tendon rupture

Within the groups no stimulation and exhausted there was no difference between the muscle force muscle tendon relations for muscle rupture and for tendon rupture

In the straight traction group 2 legs were in the danger zone Muscle ruptures occurred in both In addition 2 muscle ruptures occurred in rats with muscle force exceeding the average This makes the inclination of the regression line for the muscle force muscle tendon length relation significantly steeper for muscle ruptures than for tendon ruptures in this group and at the same time significantly steeper than for muscle ruptures in the control group This occurrence of muscle ruptures in strong rats was not observed in the control group (oblique traction) and supports the previously mentioned impression that straight traction distributes the risk of rupture to all parts of the muscle tendon group

In the control group the elongation when muscle rupture occurred was significantly greater than at tendon rupture The same tendency was found in the straight traction no stimulation and exhausted groups The separation force in these three groups did not differ for tendon and muscle rupture neither in relation to force nor to leg weight

DISCUSSION

Lindblom (1939) by traction on an abducted shoulder (in a anatomical preparation) could induce tendon rupture of the supraspinatus tendon He emphasized that by this direction of traction the articular part of the *tendon was strained (tightened) first and at this time the* acromial part of the tendon was relaxed with undulating surface He

could have produced even greater differences in the strain on various parts of the tendon by external or internal rotation of the shoulder

All tendons passing one or more joints with axes of movement at right angles to each other may be exposed to oblique traction for instance the Achilles tendon the supraspinatus tendon and the biceps brachii tendon A tendon inserting immediately distal to a hinge joint may even though it is flat be exposed to overstrain at its convex side e g the finger extensor passing the distal interphalangeal joint

If a human Achilles tendon 1.5 cm wide is exposed to traction with 30 supination of the calcaneus it may be calculated that the fibres on the convex aspect are elongated by 10 per cent before straining of the fibres on the concave side occurs This 10 per cent corresponds approximately to the values stated for the elongation of tendons at rupture (Stucke 1950 7 3 per cent Rollhauser 1954 11 5 13 5 per cent Vidik 1968 12–13 per cent)

By exerting oblique traction then it might be possible to strain a small part of the tendon and induce rupture by less force The above calculation presupposes erroneously that the tendon is homogeneous Mollier (1937) and Altmann (1963) have described the complicated structure of the tendon which in their opinion affords the best possibilities of transmitting the muscle traction to bones assuming various positions as needed The tendon fans out at the insertion and the juxtaskeletal part is stiffer than the remainder of the tendon because of its conversion into cartilaginous tissue In this way the tendon is protected from oblique traction just as the stiff cuff fitted on a flex close to an electric iron prevents breaking of the flex

At the free end of the tendon the fibres are twisted and bound to each other by interdigitation of parts of the fibres Between the fibres there is the ground substance which permits a certain displacement and thereby lends the tendon the properties of a laminated material

Cummins et al (1946) found that the human Achilles tendon was pronated 30–150 At the same time they noted that the separation of the individual fractions of the tendon derived from the soleus medial and lateral gastrocnemius was more difficult to effect the less the pronation Thus the interdigitation of the fibres appears to be alternative to rotation This perhaps contributes to determining the site of rupture so that marked rigidity and fan shape at the insertion together with marked interdigitation of the tendon fibres afford more homogeneous tendon and more proximal ruptures whereas reverse causes more distal ruptures

In the rat Achilles tendon there was pronation as in man of about 60° At the same time it was very easy to separate the components of the tendon Moreover at its insertion the tendon did not fan out as in man being collected mainly into 2 small facets laterally and medially on the posterior surface of the calcaneus Indeed the ruptures in this experimental series were localized close to the insertion although often there was a longer tendon remnant on one side (Figure 7 Barfred 1971 c) Even during straight traction the level of the rupture may be determined by the structure of the tendon Rotation of the human tendon gives rise to crossing of the fibres 2–5 cm from the insertion (Biro & Tarsoly 1967) Christensen (1954) pointed out the possibility that one part of the tendon (gastrocnemius) may damage the other part (soleus) by a saw like action at the site of crossing

In the present experimental series the incidence of tendon rupture fell from 60 to 37 per cent when the traction was straight instead of oblique This was not significant but considering the previously mentioned risk of rupture in all parts of the bone muscle tendon bone chain on straight traction it seems reasonable to assume that the oblique traction weakens the tendon in a selective way It might be imagined that the oblique traction had also caused a lower rupture limit but the reverse was found and no reasonable explanation can be advanced It seems more reasonable that the elongation at rupture was less with straight than with oblique traction

That the incidence of tendon rupture was the same in the slow group and in the control group (quick) ought to indicate that a fairly rapid movement (as in the slow group) entails the same risk to the tendon as an ultra rapid one (control group) Nevertheless the latter must be considered more dangerous as it does not allow the organism time for instituting protective measures e g relaxation of the muscle

In the group short initial length where the incidence of tendon rupture was the same as in the control group the elongation was significantly greater whereas the final length was nevertheless significantly less than in the control group Thus the elongation which may involve a danger to the tendon is easier to attain when the position of the joints at the onset of the trauma creates the shortest possible muscle tendon length

Fatigue has been stated as a contributory cause of Achilles tendon rupture (Hunter 1835 Debrunner 1950) It may be fatigue of the proprioceptive system (Debrunner 1950) i e a more central phenomenon but it may also be local changes in the muscle in the form of increased

rigidity of the myofibrils if the process of restitution cannot keep pace with the process of contraction (Lindhard 1931 Merton 1956) The present investigation indicates that the local phenomena are essential as the values for separation force elongation L_{20} as well as ΔL_{15} in the exhausted group were between those for the control group (with stimulation) and the no stimulation group

The incidence of tendon ruptures in the exhausted group was found to be of the same magnitude as in the control group whereas in the no stimulation group this incidence fell to 44 per cent which is not significantly different from the control group Although this difference is not convincing the fact that the elongation was significantly greater than in the control group gives the no stimulation group less chance of obtaining within the normal excursion the elongation which is needed for inducing rupture in the muscle tendon chain

In the exhausted as well as in the no stimulation groups the muscle appears to be weakened in relation to the stimulated muscle muscle ruptures being more common and the separation force lower This is significant for the no stimulation group In addition it was found that muscle ruptures occurred in the control group when isometric muscle force was low The contractile tissue in the muscle appears to be highly contributory to determining the site of rupture as well as the separation force and as previously mentioned the elastic stiffness

The problem whether elongation to the rupture limit is possible at all in a healthy human muscle tendon has so far been unheeded (Barfred 1971 b)

It has been mentioned above that the length at rupture in the present experimental series always exceeded the muscle tendon length In a few cases this difference was so slight that if a larger number of experiments had been carried out the final length might sometimes have been less than the maximum muscle tendon length

SUMMARY AND CONCLUSION

The bone Achilles tendon muscle bone unit in anaesthetized large wild rats was tested in a material testing machine The method has been described in detail in a previous paper (Barfred 1971 c) in which the author disproved the claim that a healthy tendon never ruptures The rupture experiment was performed rapidly during tetanic stimulation of the muscle using an oblique traction and an initial length corresponding to the elastic equilibrium length

To ascertain the importance of the individual factors it was endeavoured in the present study to alter only one of the named experimental conditions at a time

The findings were as follows

(1) The incidence of tendon rupture was the same with slow and quick traction
(2) An oblique traction on the calcaneus appeared to concentrate the risk of rupture on the tendon in experiments comprising the bone tendon muscle bone unit
(3) Muscle ruptures occurred mainly when the isometric muscle force was below average
(4) The resting muscle appeared to be weaker than the tendon
(5) An exhausted non stimulated muscle occupied a position intermediate between stimulated and non stimulated muscle as far as the parameters of the rupture experiment were concerned
(6) The incidence of tendon rupture was the same in the exhausted and in the control group
(7) The possibility of inducing tendon rupture without exceeding the maximum muscle tendon length in the leg was slight but
(8) this possibility would be greatest at a short initial length
(9) Elongation was less when the rupture experiment resulted in tendon rupture than when it caused muscle rupture

It may be concluded that subcutaneous rupture of the Achilles tendon in the rat is conceivable in nature although presumably it is very rare The greatest possibility of tendon rupture is present when the loading on the tendon is oblique when the muscle is in maximum contraction when the muscle is exhausted and when the initial length is short

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